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SENT VIA ELECTRONIC MAIL

January 15, 2020

Ms. Melanie Morash
U. S. Environmental Protection Agency (USEPA), Region 1
5 Post Office Square, Suite 100,
Mail Stop OSRR07-4, Boston, MA 02109-3912

RE: DAPL Volume and NDMA Mass Calculations
Olin Chemical Superfund Site (OCSS; "Site") – Wilmington, MA

Dear Ms. Morash:

As a follow-up to the discussions between USEPA and Olin, and as requested by USEPA at the October 2 and 3, 2019 meeting, transmitted herewith is a technical memorandum that summarizes Olin's analyses/conclusions presented during the meeting related to N-nitrosodimethylamine (NDMA) mass within the hot spot diffuse layer above the dense aqueous phase liquid (DAPL) pools. A copy of the presentation that Olin gave during the meeting is also included as an attachment to the memorandum.

Let us know if you have any questions.

Sincerely,
OLIN CORPORATION

James M. Cashwell
Director, Environmental Remediation

Enclosure

cc: Chinny Esakkiperumal (Olin)
Andy Davis (Geomega)
Steven Humphrey (Geomega)
Libby Bowen (Wood)

Memorandum

TO: J. Cashwell, C. Esakkiperumal

FROM: A. Davis, S. Humphrey

DATE: January 3rd, 2020

RE: **DAPL Volume and NDMA Mass Calculations for the Olin Chemical Superfund Site, Wilmington, MA**

Executive Summary

A meeting was held in Boston at the United States Environmental Protection Agency (USEPA) Region 1 office on October 2 and 3, 2019 to discuss Interim Action Feasibility Study (IAFS) alternatives. General concurrence on alternatives for NDMA groundwater "hot spot" (>5,000 ng/L) removal and source control was reached between the USEPA and Olin. Olin presented its findings that the NDMA mass within the hot spot diffuse layer above the DAPL pools is minimal compared to the NDMA within the DAPL pools themselves and hot spots in areas without DAPL. The results of the NDMA mass calculation indicate that the hot spot within the diffuse layer at the Main St. DAPL pool has minimal NDMA mass compared to the underlying DAPL pool (140 grams [6%] versus 2,170 grams [94%]). Thus, targeting removal of NDMA above areas where DAPL is actively being removed is unnecessary and redundant, since the DAPL removal will also remove the diffuse NDMA mass. USEPA requested a copy of the Olin presentation from the October 2/3 meeting as well as a memorandum that documents Olin's conclusions. As requested, Olin updated the presentation to reflect meeting discussions and sent it electronically to the USEPA on October 10, 2019 (the presentation is also included as Attachment A to this memo). This document responds to USEPA's request for a memorandum of Olin's conclusions presented during the meeting. Additional data will be collected (as part of the data gaps investigation) to verify the NDMA mass in diffuse layer above the DAPL pools.

Introduction

The purpose and objective of this memorandum is to evaluate and calculate DAPL pool volume and NDMA mass estimates, and to provide an assessment of the practicality of NDMA mass removal in the diffuse layer overlying the DAPL pools concurrent with DAPL removal.

The following subsections present Geomega's methodology related to DAPL pool volume and NDMA mass estimates in both DAPL and overlying diffuse groundwater, and compares those results to estimates by Nobis Group (Nobis 2019). DAPL volume estimates are also compared to earlier Wood Environment & Infrastructure Solution (Wood) estimates. The DAPL pool volumes estimated by Wood and Geomega were as much as 60% less than Nobis estimates mainly due to different assumptions used to determine the geometry of the DAPL pools. The Draft Data Gaps Work Plan (Olin 2019) that is currently under review by USEPA will address the bedrock surface in DAPL pool areas to verify and update the DAPL pool volume estimates.

While the Geomega calculations of DAPL volume and NDMA mass differ from the Nobis calculations, the Nobis DAPL volume estimates have been adopted and updated using 2019 NDMA concentrations for the purpose of IAFS costing.

Evaluation of DAPL Pool Volumes

There are three DAPL pools discussed in this memo: 1) On-Property DAPL pool, referred to as the Containment Area, 2) the Off-Property West Ditch DAPL pool, referred to as Jewel Drive, and 3) the Main Street DAPL pool. The volumes for the DAPL pools were calculated using the most recent data (March-May 2019; and August 2019 groundwater analytical data set), in conjunction with the available bedrock surface topography and groundwater chemistry data to estimate the top of DAPL (ToD) and the top of diffuse layer elevations. The DAPL volumes calculated for each of the areas by Nobis (Nobis 2019) are also included for comparison.

Geomega independently calculated the ToD using the 2019 sampling data from the multiport (MP) wells located within each DAPL pool (MP-1 for the Containment Area [Table 1], MP-2 for Jewel Drive [Table 2] and MP-3 for the Main Street DAPL pool [Table 3]). A specific gravity (SG) greater than 1.025 was used as the primary metric to define the ToD criteria (Geomega 1999; 2019). In cases where both SG and SC are available, SG data was used to define ToD because it is a direct measurement of the media density. The ToD elevation was conservatively established using the base of the highest sampling port screen with SG below the criterion of 1.025. A specific conductivity (SC) greater than 20,600 µS/cm was used as the secondary metric to define the ToD (Geomega 2019). For example, Table 1 shows the data for the Containment Area where the ToD was established at the base of port 3 (51.4 ft amsl) according to the SG data. A SC greater than 3,000 µS/cm was used as the primary metric to define the top of diffuse layer, and a SG greater than 1.011 was used as a secondary metric (Geomega 1999; 2019).

Schematic cross sections of each DAPL pool are presented in Figures 1 through 4 and depict the extrapolated data and assumed horizontal surface of the ToD and top of diffuse layer. The

Geomega ToD elevations generally compared well (within 0.5 feet) to the Wood values provided in the OU3 Remedial Investigation (RI) Report (Wood 2019a), which relied on the most recent available data. Geomega ToD elevations generally compared well to the Nobis values, but the Geomega estimates for ToD were lower for both the Main Street and Containment Area DAPL pools (Table 4) because Nobis relied on the 2012 and earlier data to determine the ToD. We understand that the recent data used in this memo were not available to Nobis when they prepared their report. Irrespective of the use of different datasets, we believe the approaches by Nobis are similar to the approach outlined in this memo and both approaches will result in similar estimates if Geomega and Nobis were to use the same datasets.

The Geomega DAPL volume calculation (Figure 5) summed 1-foot thick layers of elevation areas derived from the bedrock contours below the ToD, generally consistent with the Nobis (Nobis 2019) method. In comparison, Wood used Surfer ™ to develop a 3D volumetric model to compute DAPL volumes directly from the bedrock contours. The bedrock surface topography and DAPL pool extents presented in the Draft 2019 IAFS (Wood 2019b) were used for the DAPL volume calculations. A porosity of 25% (consistent with Nobis 2019) was adopted resulting in the following equation used to calculate the DAPL volume:

$$Volume = \sum_{layers} [Area \times Thickness] \times 0.25$$

The Geomega and Wood DAPL volumes are similar, and generally compared well to the Nobis calculations except for the Containment Area and Main Street DAPL pools (Table 4). For the Containment Area pool, Nobis appears to have adopted a base DAPL elevation of 50 feet amsl, which is approximately 5 feet higher than the bedrock surface based on the available data. The lowest recorded bedrock elevation in the Containment Area was from the MP-1 lithologic log (45.9 feet). This discrepancy is apparent in Figure 2 of the Nobis memo (2019) (see Figure 6 of this memo).

For the Main Street DAPL pool, Nobis assigned a ToD of 54.9 feet using 2012 groundwater chemistry, which is 3.5 feet higher than the ToD based on 2019 chemistry (51.4 feet). The difference between the Geomega and Nobis Main Street DAPL volume is primarily due to Nobis calculating a higher ToD (42 feet versus 38.5 feet) based on 2012 chemistry. Regardless, as requested by USEPA, NDMA mass calculations for the revised IAFS will be based on the Nobis DAPL volumes.

Estimated NDMA Mass in DAPL

The NDMA mass in each DAPL pool was calculated by Geomega using the 2019 analytical results from the MP wells. The NDMA data from each port was assigned to corresponding elevation layer(s) within the DAPL across the pool as described above. The elevation of the top of the port screen between the sampling ports was used to vertically define the volumetric layers within the DAPL that are used to estimate mass. The NDMA concentrations were multiplied by the pore volumes and summed to estimate total mass (Figure 7).

As discussed during the meeting, the DAPL volumes calculated by Nobis were adopted to calculate the NDMA DAPL mass using 2019 data for comparison purposes. The same method of vertically correlating NDMA concentrations from the MP wells was used with the Nobis DAPL volumes. As discussed in the prior section, there are discrepancies in the calculated volumes for the Containment Area and the Main Street DAPL pools. In the Containment Area, MP-1 port 1 is below the bottom of the inferred Nobis DAPL pool (elevation of 46.4 feet versus 50 feet). To account for this difference, the MP-1 (port1) NDMA concentration was assigned to the basal layer (50-51 ft amsl) of the Nobis DAPL volume. In the Main Street DAPL pool, the discrepancies were not substantial enough to require significant modifications; MP-3 port elevations were directly correlated with the Nobis DAPL volume layer elevation intervals.

Consequently, the Geomega NDMA mass estimates for the DAPL pools (Table 5) differ from the Nobis calculations, primarily due to the difference in NDMA concentrations between 2012 and 2019. However, as agreed at the October 2/3 meeting, the Geomega NDMA mass calculations use the Nobis DAPL volumes for each DAPL pool.

Estimated NDMA Mass in the Main Street Hot Spot Diffuse Layer

The top of the hot spot diffuse layer at the Main Street DAPL pool was established using the base of the port where the NDMA concentration was below 5,000 ng/L (i.e., MP-3 port #5; 1,200 ng/L; Figure 5). The 2019 specific conductivity[1] measurements from MP-3 were used to estimate the top of the hot spot diffuse layer at an elevation of approximately 55 feet (Figure 1). The same method to calculate NDMA mass in the DAPL pool was used for the hot spot diffuse layer for Main Street. The results of the calculation indicate that the hot spot within the diffuse layer has minimal NDMA mass compared to the underlying DAPL pool (140 grams [6%] versus 2,170 grams [94%]). The relatively small amount of mass in the diffuse layer along with current observations of the effects of ongoing DAPL removal at Jewel Drive, indicate that targeting hot spot NDMA concentrations in areas within DAPL pools would not be effective. An analysis of the effects of DAPL removal on NDMA concentrations in the diffuse layer is discussed in the following section.

[1] There were no 2019 specific gravity measurements for the diffuse layer.

Analysis of DAPL Removal Effects at Jewel Drive

DAPL removal from the Jewel Drive DAPL pool over the past 7 years (since December 2012) demonstrates the effect of drawdown. Approximately 1 million gallons of DAPL has been withdrawn between the initial pilot study (AMEC 2014; 2015) and post-pilot extraction. Throughout the period of DAPL extraction from Extraction Well 1 (EW-1), nearby multi-port well MP-2 and multi-level monitoring wells ML-1 and ML-2 were monitored on a frequent basis (Figures 8 and 9). The wells were monitored to determine if the DAPL drawdown at EW-1 was consistent with DAPL elevation changes in other parts of the pool.

The primary indicators to track DAPL and overlying diffuse layer behavior during extraction were specific conductivity and pH. Pumping at higher, less sustainable rates (0.5, 1.0 and 2.0 gpm) resulted in excessive drawdown of DAPL in the vicinity of EW-1 compared to MP-2. During recovery periods after completion of the formal Pilot test, DAPL elevations near EW-1 recovered while the DAPL elevation away from EW-1 (i.e., MP-2) continued to decline as the DAPL elevations equilibrated across the pool. When DAPL elevations reached equilibrium, the elevation of DAPL in MP-2 and ML-1/ML-2 were the same (within measurement accuracy). Comparing specific gravity datasets from MP-2 between 2012 and 2019 shows a measurable reduction in ToD elevation (Table 6). Data from ML-1 and ML-2 indicate a DAPL elevation reduction on the order of 5 feet, consistent with the volume of DAPL removed. Current interpreted DAPL elevations at MP-2 and ML-1/ML-2 after the last twelve months of DAPL extraction at 0.25 gpm show a uniform DAPL elevation and drawdown across the monitored portion of the pool, which indicates the lower pumping rate is more sustainable. Pumping has also reduced the elevation of the diffuse layer because ports that were originally characterized as diffuse layer (ports #5 and #6) now have conductivities below 3,000 µS/cm and are no longer diffuse groundwater, while ports #2 and #3, which were originally DAPL are now diffuse layer (Table 6). Therefore DAPL pumping has resulted in a uniform lowering of both the DAPL interface and the diffuse layer, while also reducing the apparent thickness of the diffuse layer (2 feet versus 5 feet). The effects of DAPL removal have also reduced NDMA concentrations within the DAPL pool by approximately 1 order of magnitude (Table 6). The specific conductivity versus time plots for ML-1/ML-2 (Figure 8), and MP-2 ports #3 and #4 (Figure 9) also reflect the effects of DAPL drawdown.

The removal of approximately 1 million gallons within 7 years of pumping has decreased the ToD for the Jewel Drive DAPL pool by approximately 5 feet, and the top of the diffuse layer has decreased by approximately 6 feet (Table 6; Figure 8 and Figure 9). In addition, the diffuse layer solute concentrations have decreased by an order of magnitude. These changes reflect how DAPL removal at carefully managed rates (0.25 gpm) effectively reduces both the NDMA mass in the DAPL and lowers the diffuse layer level.

Strategies to Remove NDMA Mass in DAPL and Hotspot

The IAFS alternatives for Main Street DAPL pool removal include DAPL extraction at multiple well locations that would potentially result in removal of the Main Street DAPL pool in approximately six years. As requested by USEPA, the IAFS alternatives for NDMA hotspot groundwater removal include extraction of hotspot groundwater (>5,000 ng/L) from 2 to 4 short screen extraction wells within the narrow interval in the diffuse layer above the ToD, (i.e. within 2 feet of the DAPL- diffuse layer interface).

The medium to coarse sands and gravelly sands present within the diffuse layer have adequate transmissivity to install short screen extraction wells within this narrow interval above the DAPL interface. However, even relatively low pumping rates (10 gpm) will result in excessive drawdowns near the extraction wells that will promote upwelling, entrainment and capture of DAPL immediately underlying the base of the well screen. There is ample evidence of this at higher pumping rates from the former Sanmina wells which were screened some 20 feet above the DAPL.

In addition, as discussed above, operation of the Jewel Drive DAPL pilot extraction system has definitively shown that lowering of the DAPL interface during DAPL extraction results in lowering and thinning of the diffuse layer that lies immediately above the DAPL/diffuse layer interface, with concomitant reductions in NDMA and other constituent concentrations. DAPL extraction would be occurring simultaneously with hotspot groundwater extraction. The projected 6-year time frame for DAPL extraction means that the elevation of both the DAPL/diffuse layer and diffuse layer/groundwater interfaces would be lowered by several feet each year.

Therefore, if groundwater hotspot extraction wells were to be installed, they would very quickly become stranded above the diffuse layer in overlying groundwater with much lower NDMA concentrations rendering these hotspot groundwater extraction wells ineffective in capturing NDMA mass (no longer hotspot groundwater).

In summary, given that DAPL will be extracted, targeting and extracting the NDMA hot spot above the DAPL has no meaningful cost/benefit because:

1. The majority of NDMA mass is within the DAPL pool,
2. Removing DAPL will also remediate the hot spot above Main Street DAPL pool – a similar effect is being observed in the ongoing Jewel Drive DAPL removal (see details in the Section above),
3. The ongoing DAPL removal will draw down the DAPL/diffuse layer zone, rendering the initial well elevations ineffective (i.e., stranded), and

4. The initial pumping of the hot spot diffuse layer will cause upwelling of the DAPL, resulting in precipitation of solids that will potentially clog the sand pack and well screen of the wells.

To further demonstrate the ineffectiveness of installing extraction wells in the diffuse layer to remove NDMA mass, a simple analytical simulation of mass removal using extraction wells was developed. The NDMA mass with the Main Street DAPL pool (2,170 grams) was assumed to be removed using four DAPL extraction wells targeting DAPL removal. If four additional wells were installed to target the NDMA within the diffuse layer, only an additional 140 grams (6%) of NDMA would be removed (Figure 10).

Conclusions and Recommendations

The evaluation of DAPL volumes and NDMA mass using the most recent 2019 analytical dataset, presented in this memorandum is appropriate to support the IAFS. The Nobis volume calculations were adopted in conjunction with the 2019 NDMA concentrations to calculate the NDMA mass within the DAPL pools (Table 5) and provide conservative values for IAFS cost estimates.

The DAPL volume and affiliated NDMA mass calculations show that there is up to 6% NDMA mass in the hot spot diffuse layer relative to that in the DAPL pools. Consequently, extraction wells in the hot spots above the DAPL would remove minimal mass of NDMA compared to those wells used to extract DAPL. In addition, the vertical geometry of extraction wells placed in the diffuse layer is problematic for two reasons: 1) their operation would initially cause an upwelling of DAPL compromising their integrity, and 2) with progressive DAPL extraction from the bottom of the pool, they would quickly become stranded in overlying groundwater; rendering them ineffective. In contrast, the DAPL extraction wells can be utilized to extract diffuse groundwater once the DAPL is removed because the diffuse layer has been demonstrated to be drawn down as the DAPL is removed.

Finally, the data gaps work plan includes the installation of additional MP wells to further characterize the DAPL and diffuse layers within the DAPL pool areas. The data collected from these new wells will be used to update the DAPL and diffuse layer elevations, volumes, and mass calculations.

References

AMEC. 2014. DAPL Extraction Pilot Study Performance Evaluation Report, Olin Chemical Superfund Site, 51 Eames St., Wilmington, Massachusetts. November 7, 2014.

AMEC. 2015. Memorandum referencing the DAPL Extraction Pilot Study Performance Evaluation Report. Subject: Supplemental Water Level and Hydraulic Analysis February 5, 2015.

Geomega. 1999. Olin Wilmington Technical Series III: Results of the August 1998 Multilevel Piezometer Sampling Event and DAPL/Diffuse Layer Discrimination Analysis. January 1999.

Geomega. 2019. Responses to Selected EPA Comments on the Draft RI for OU3. Technical Memorandum prepared for Olin. November 16, 2018.

Nobis Group. 2019. Olin Chemical Superfund Site: Revised evaluation of DAPL and NDMA to support Feasibility Study review and development of DAPL and groundwater alternatives v5. Technical Memorandum prepared for USEPA, File 80021. July 19, 2019.

Wood Environment & Infrastructure Solutions. 2019a. Revised Remedial Investigation Report, Operable Unit 3, Olin Chemical Superfund Site, Wilmington, Massachusetts. Project No. 6107190016. June 2019.

Wood Environment & Infrastructure Solutions. 2019b. Draft Interim Action Feasibility Study, Olin Chemical Superfund Site, Wilmington, Massachusetts. Project No. 6107190016. April 2019.

Tables

Table 1. March - May 2019 data summary for Containment Area DAPL pool (MP-1).

Port	Port Base Elevation (ft amsl)	Specific Gravity Measured	Specific Conductivity (µmohs/cm)	NDMA (ng/L)
18	78.9		1,047	**0.44**
14	69.9		798	41
11	65.4		778	39
8	60.9		832	42
6	57.9	1.003	1,853	240
4	53.9	1.004	6,966	**4,600**
3	51.4	1.018	25,181	**13,000**
1	46.4	1.091	84,774	5,600

Diffuse layer.

DAPL.

Red - resampled in August 2019.

Table 2. March - May 2019 data summary for Jewel Drive DAPL pool (MP-2).

Port	Port Base Elevation (ft amsl)	Specific Gravity Measured	Specific Conductivity (µmohs/cm)	NDMA (ng/L)
15	72.6		1,552	ND
11	65.6		1,533	40
9	60.6		1,393	**35**
7	57.6		1,570	48
6	56.1	1.000	1,642	56
4	53.1	1.053	3,431	240
3	50.6	1.063	6,865	**920**
1	45.6	1.049	63,766	9,700

Diffuse layer.

DAPL.

Red - resampled in August 2019.

Table 3. March - May 2019 data summary for Main Street DAPL pool (MP-3).

Port	Port Base Elevation (ft amsl)	Specific Gravity Measured	Specific Conductivity (µmohs/cm)	NDMA (ng/L)
21	76		256	ND
20	74.5		354	ND
19	73		3,528	**4.3**
18	71.5		754	ND
17	68		1,436	0.44
16	64.5		1,681	0.43
15	61		2,277	1.5
14	57.5		2,678	0.43
13	55		1,755	ND
12	53.5		3,392	1.7
11	52		3,537	3.9
10	50.5		622	ND
9	49		3,783	5.5
8	47.5		3,822	6.4
7	46	1.001	3,923	**23**
6	44.5	1.005	4,084	32
5	42	1.001	4,962	**1,200**
4	38.5	1.008	9,684	**18,000**
3	34	1.021	29,010	**50,000**
2	29.5	1.047	49,846	**36,000**
1	24	1.059	64,184	15,700

Diffuse layer.
Hot spot layer.
DAPL.

Red - resampled in August 2019.

Table 4. Comparative top of DAPL and DAPL pool volumes.

	Main Street	Jewel Drive	Containment Area
Top of DAPL (ft amsl)			
EPA/Nobis (recommended)	42	49.4	54.9
EPA/Nobis (EPA CSM)	42	49.4	54.9
Geomega	**38.5**	**50.6**	**51.4**
Olin OU3 RI	39.25	48.9	51
DAPL Pool Volumes (Million Gallons)			
EPA/Nobis (recommended)	17.5	1.4	0.61
EPA/Nobis (EPA CSM)	21.2	1.4	0.66
Geomega	**13.3**	**1.3**	**0.24**
Olin OU3 RI	13.2	1.2	0.20

Table 5. NDMA mass in DAPL estimates (grams).

Location	Nobis	Geomega	Geomega w/Nobis Volume
Main Street DAPL Pool	980	2,170	2,510
OPWD DAPL Pool	14	21	25
Containment Area DAPL Pool (base of port #4)	2.4	29	38

Table 6. Jewel Drive DAPL reduction parameters (2012 versus 2019).

Jewel Drive (MP-2)						
Port	**Port Base Elevation (ft amsl)**	**2012 Specific Gravity Measured**	**2012 Specific Conductivity (uS/cm)**	**2019 Specific Gravity Measured**	**2019 Specific Conductivity (uS/cm)**	**2019 NDMA (ng/L)**
10	63.6	--	2,712	--	--	--
9	60.6	1.004	--	--	1,393	35
7	57.6	1.004	3,308	--	1,570	48 **(420)**
6	56.1	1.008	4,787	1	1,642	56 **(1,100)**
4	53.1	1.03	28,509	1.005	3,431	240
3	50.6	--	51,771	1.063§	6,592	760
1	45.6	1.1	--	1.053	63,219	9,700 **(2,500)**

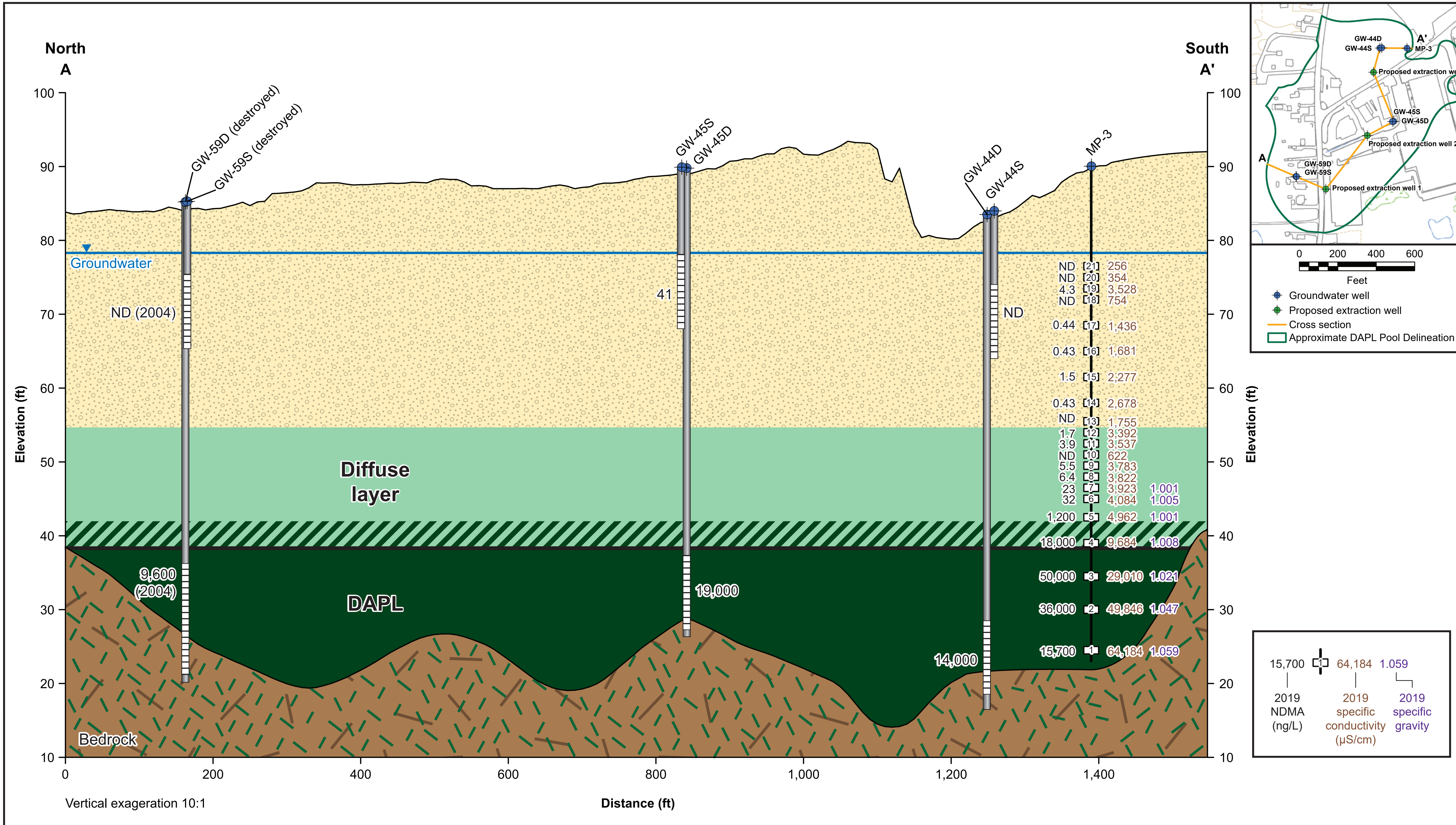
Bold - pre-2012 NDMA data

§ SG inconsistent with SC.

Diffuse layer.

DAPL.

Figures



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Main Street 2019 DAPL section A-A' with NDMA (black), specific conductivity (brown), and specific gravity (blue) analytical results.

Figure
1

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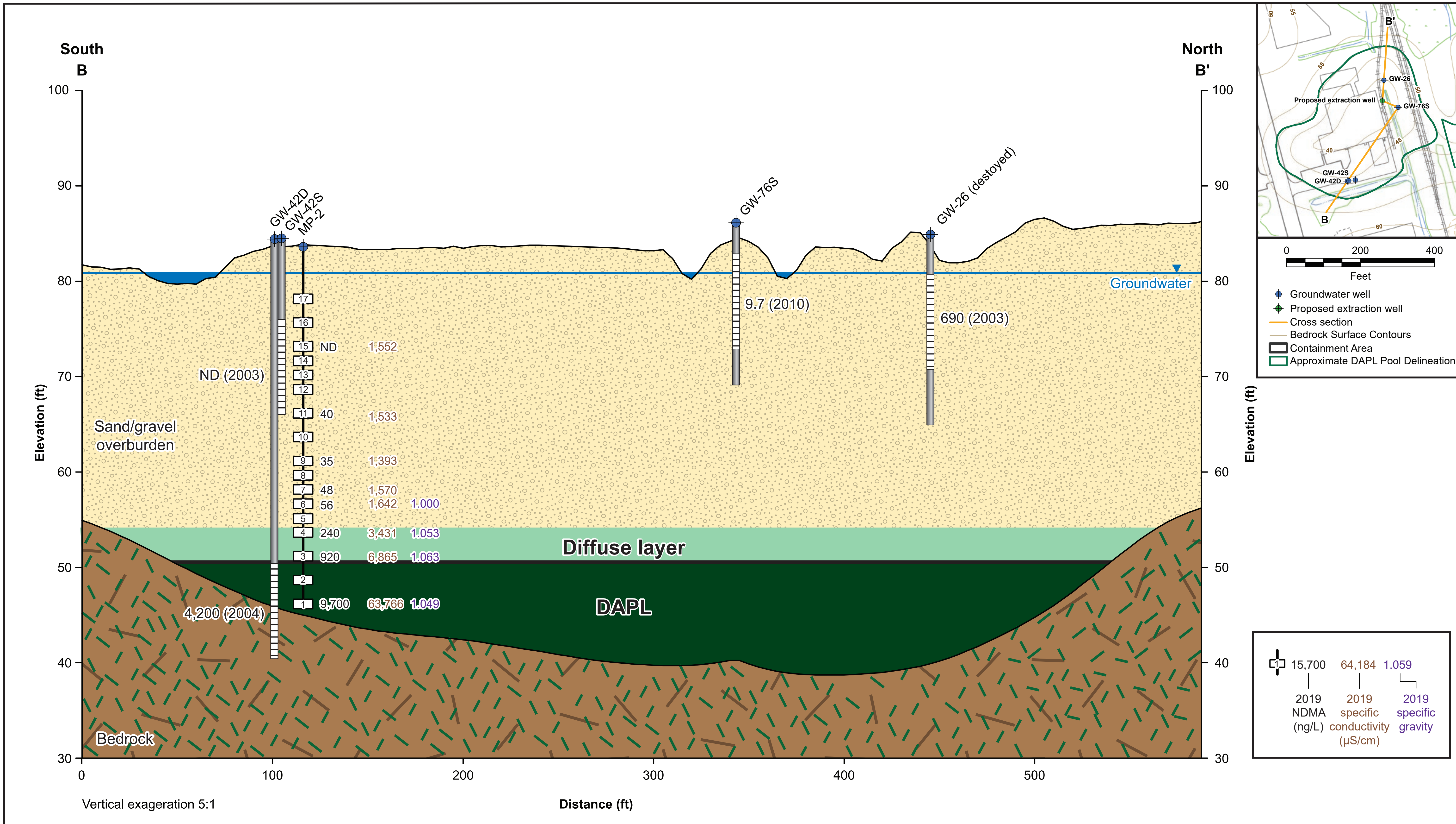

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Off-Property West Ditch (OPWD) 2019 DAPL section B-B' with NDMA (black), specific conductivity (brown), and specific gravity (blue) analytical results.

Figure
2

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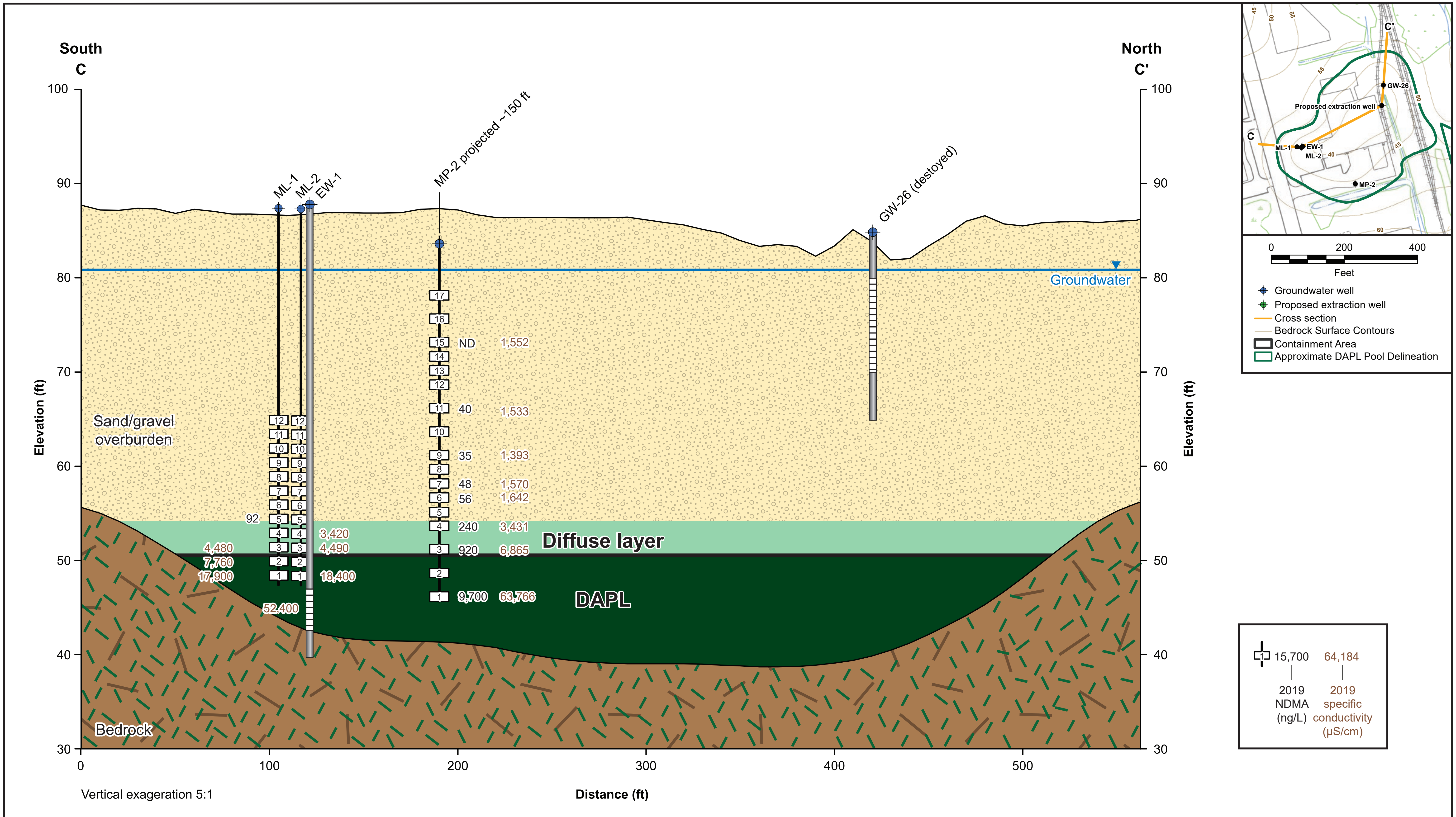

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Off-Property West Ditch (OPWD) 2019 DAPL section C-C' with NDMA (black), and specific conductivity (brown) analytical results.

Figure 3

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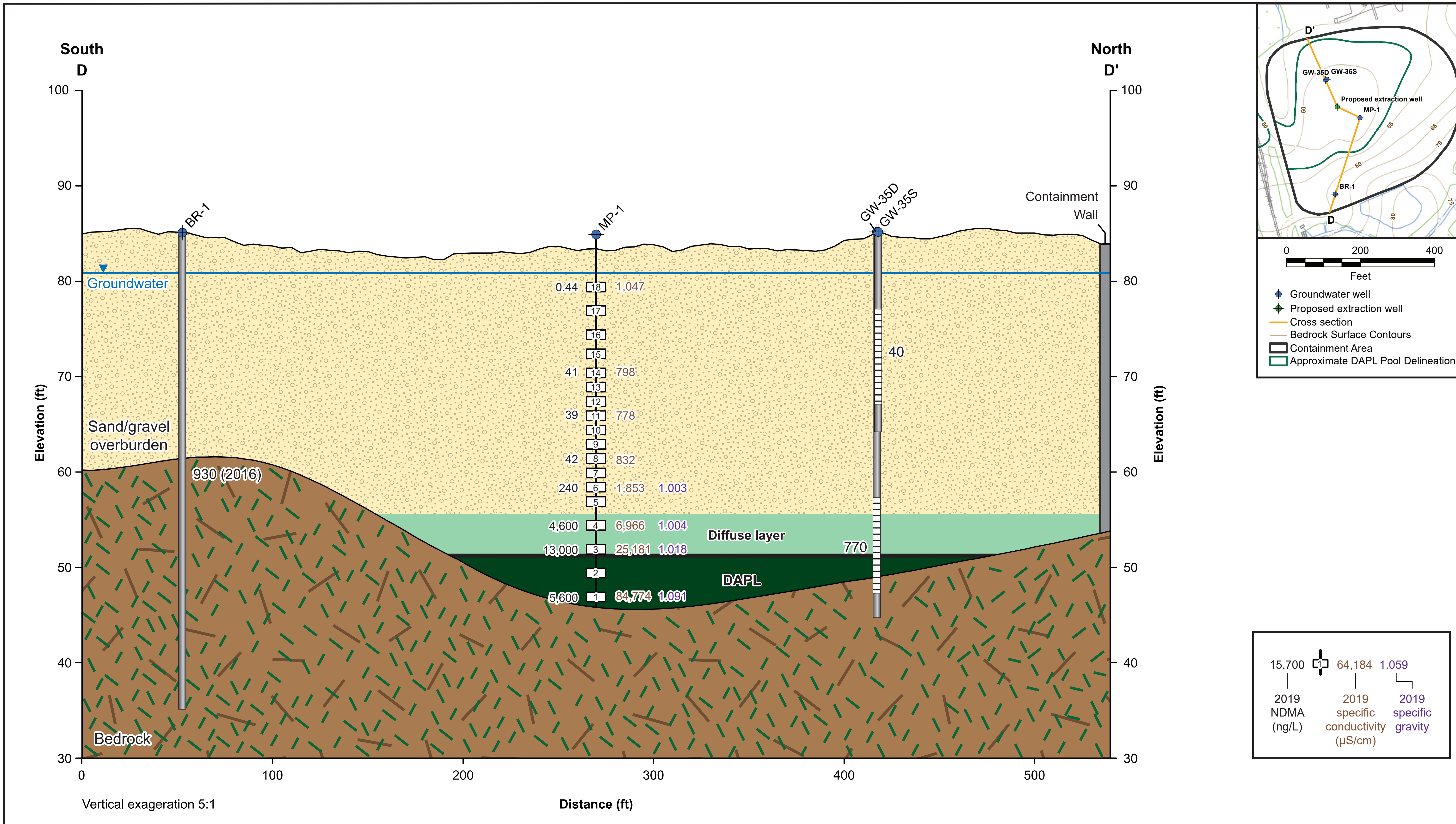

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Containment Area 2019 DAPL section D-D' with NDMA (black), specific conductivity (brown), and specific gravity (blue) analytical results.

Figure
4

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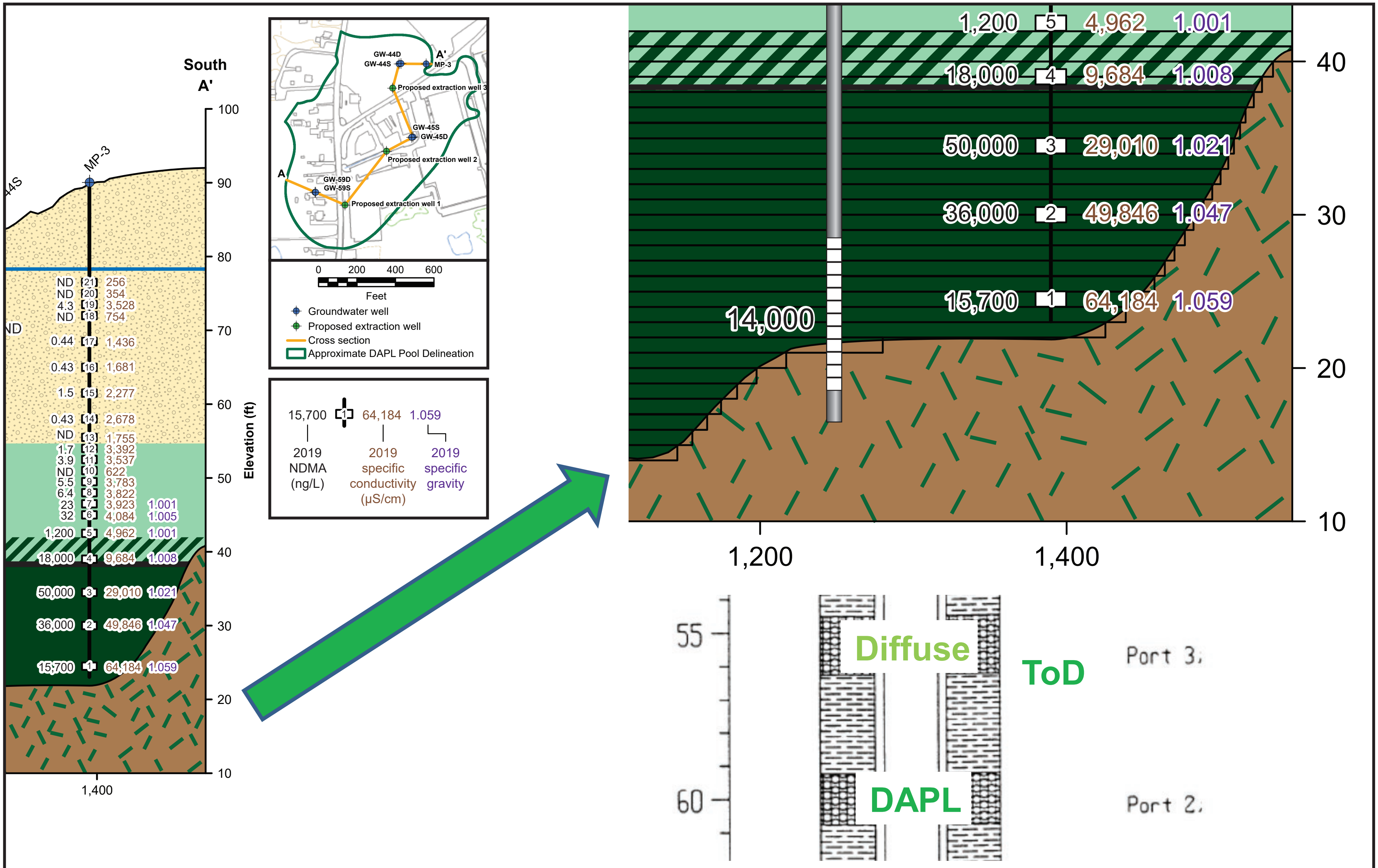

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DAPL volume calculation schematic with NPMA (black), specific conductivity (brown), and specific gravity (blue) analytical results.

Figure
5

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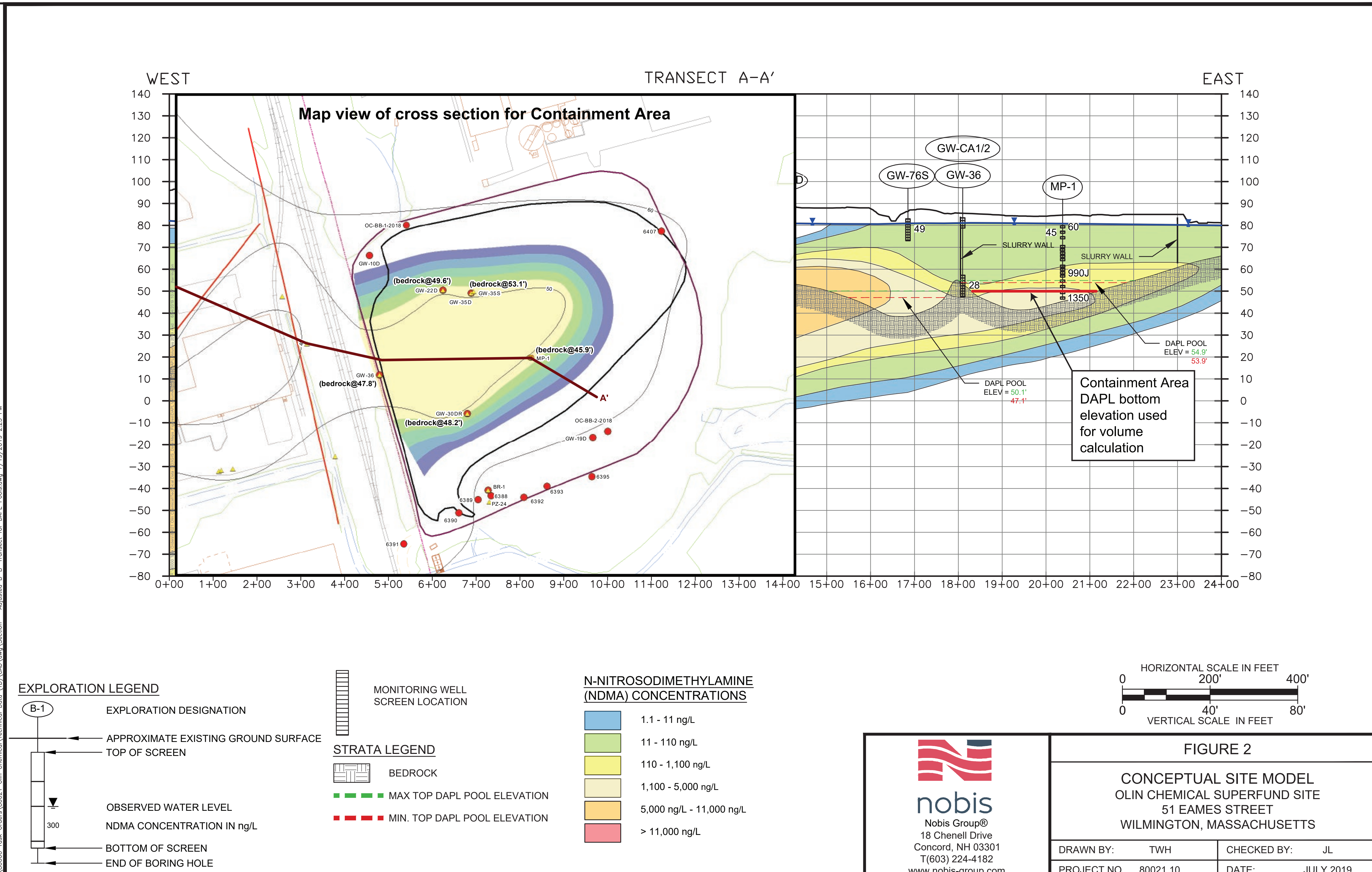

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Cross section view of Containment Area and Nobis DAPL volume calculation (modified from Nobis 2019).

Figure
6

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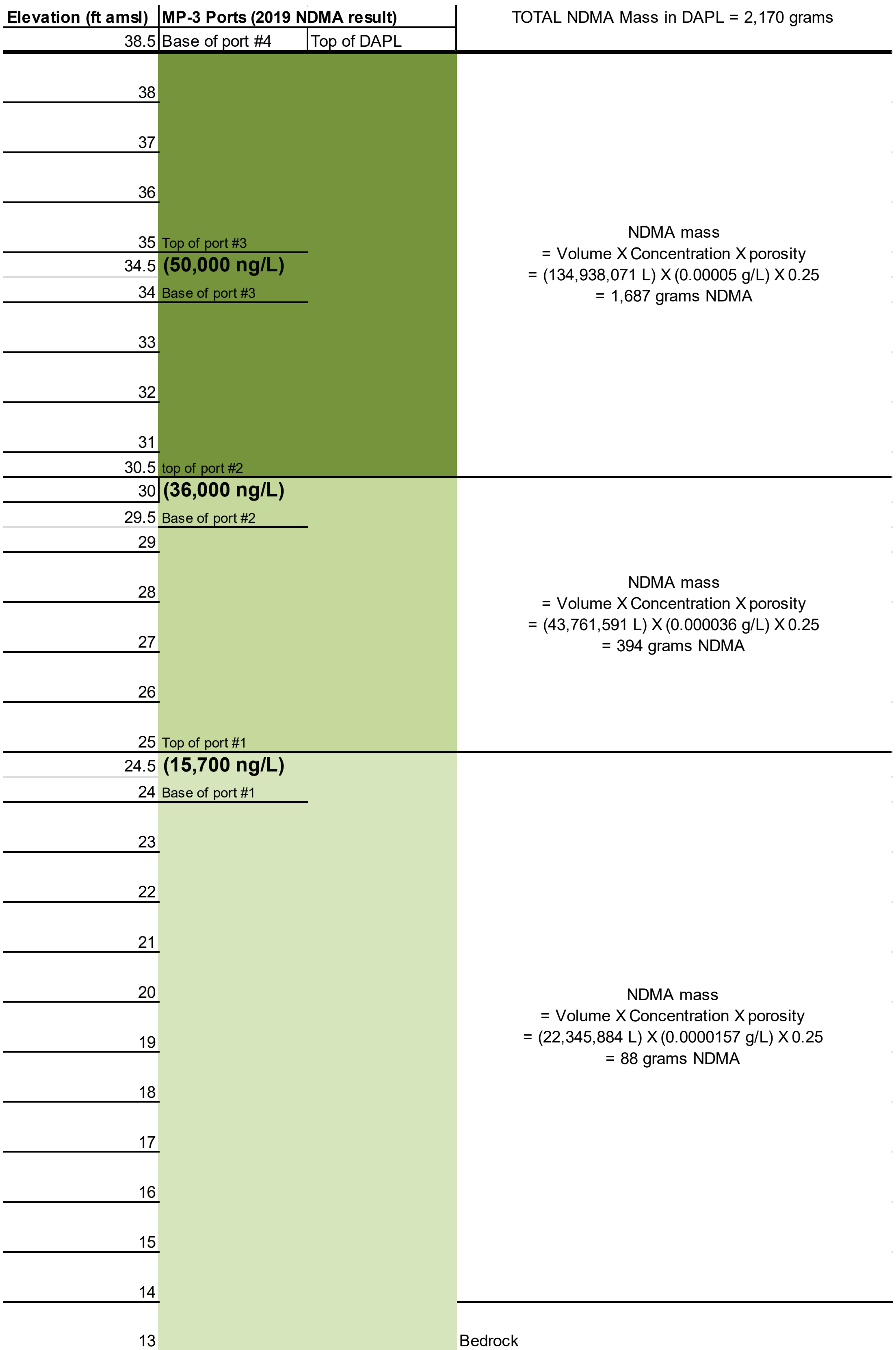

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NDMA mass calculation schematic.

Figure
7

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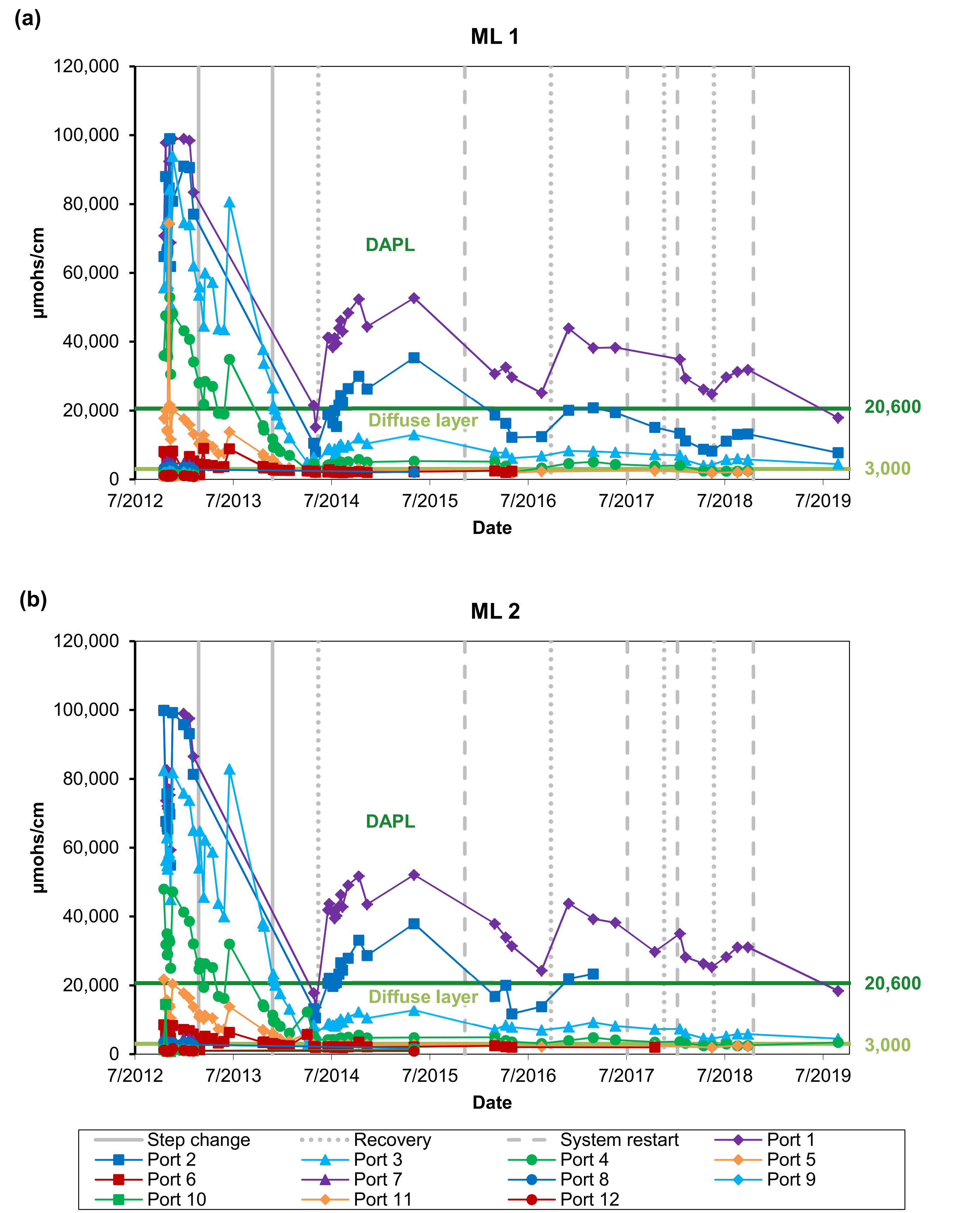

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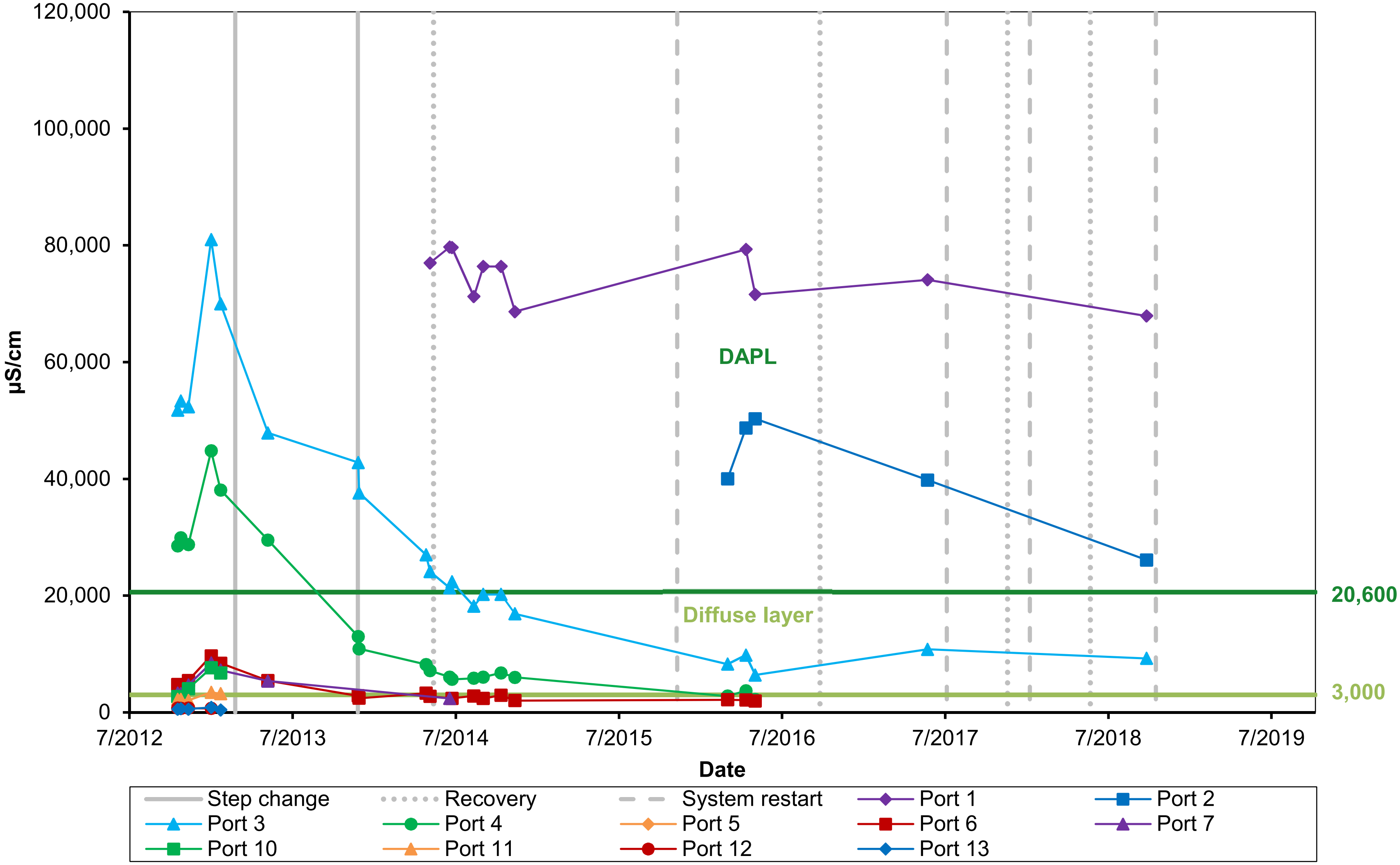
Multi-level monitoring data for DAPL extraction at the Jewel Drive DAPL pool for (a) ML 1 and (b) ML 2.

Figure
8



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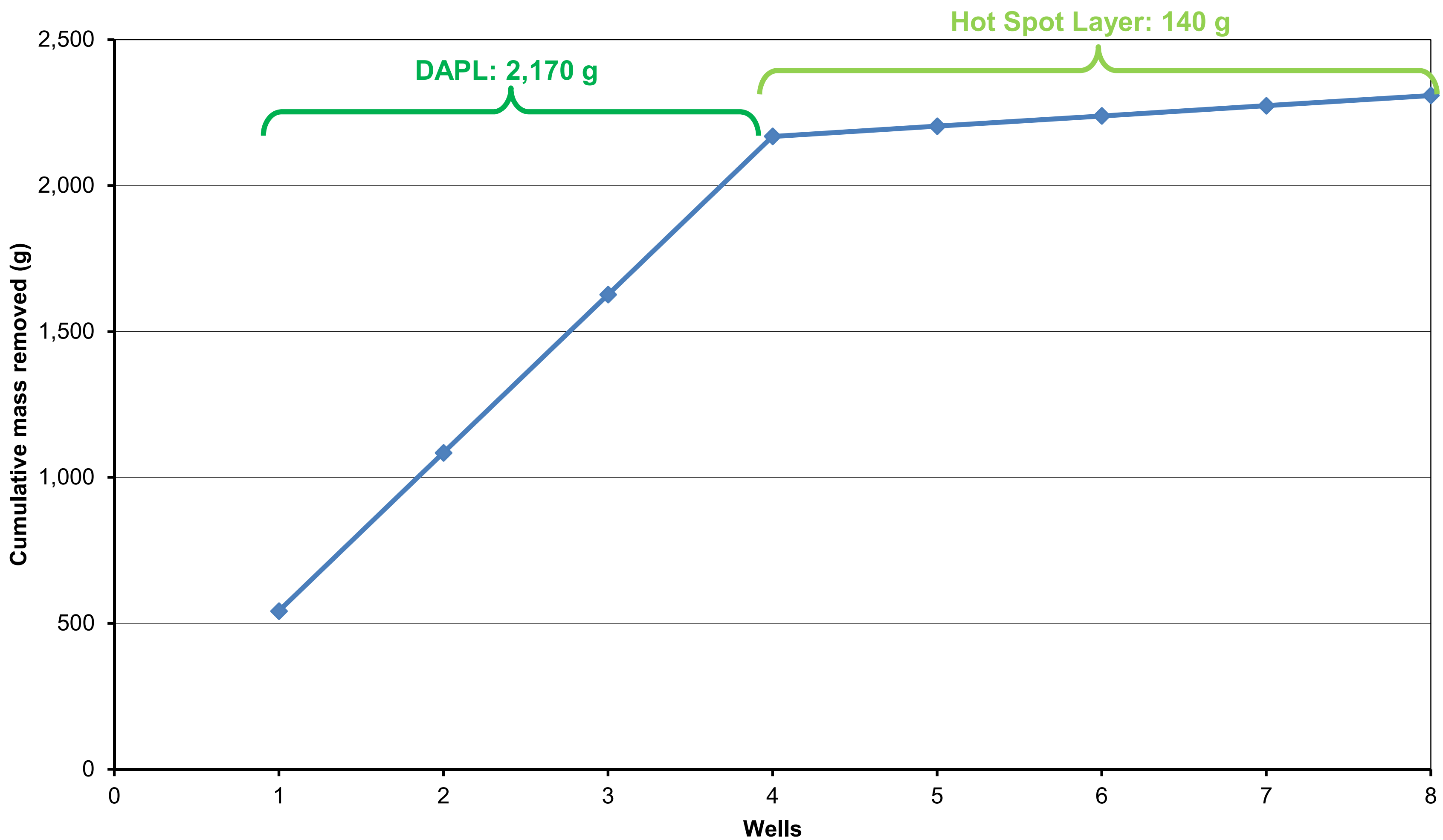
Specific conductance versus time In MP-2.

Figure
9



GEOMEGA

11/22/19

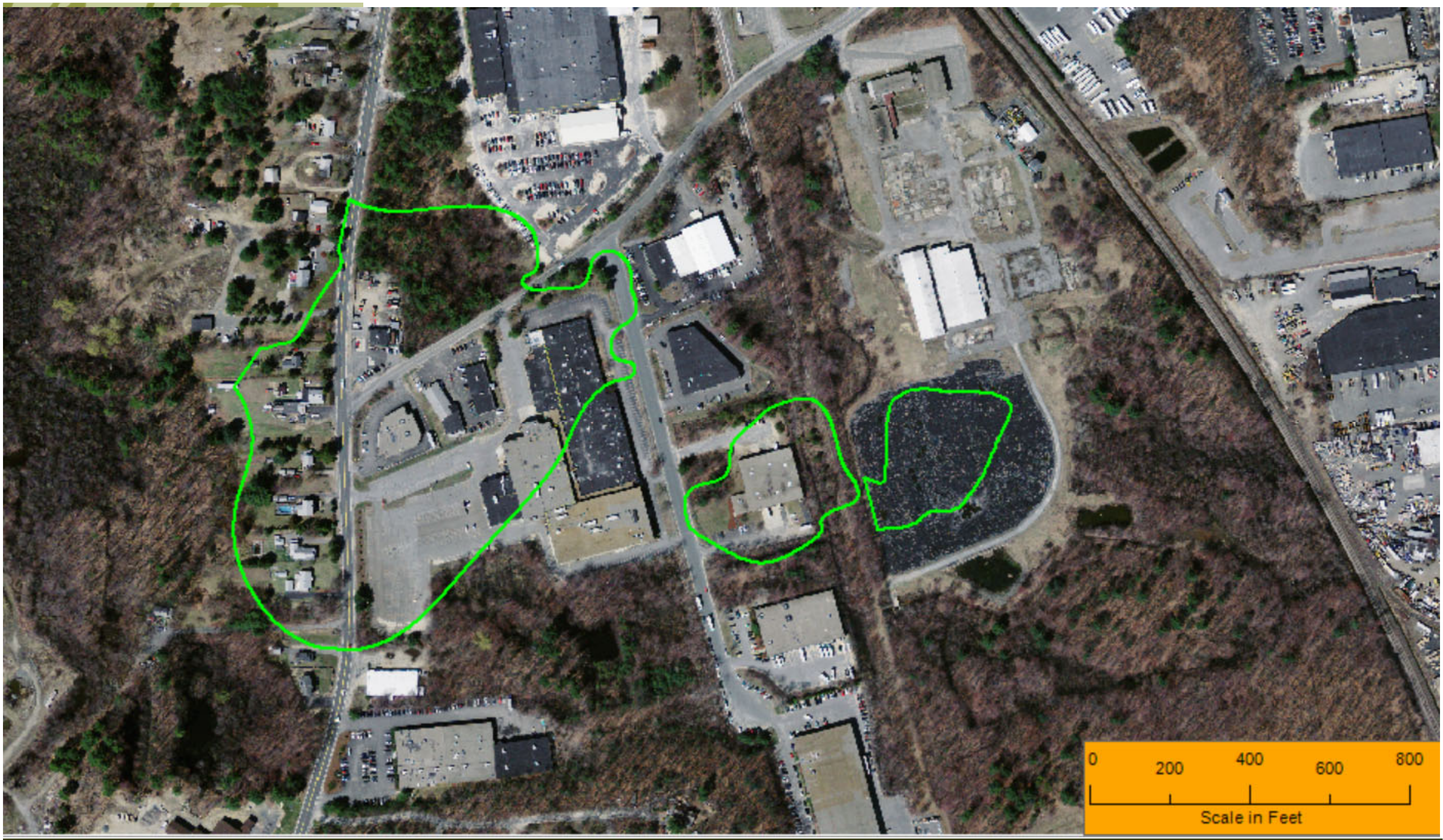
C181086
Olin

Cumulative simulated NDMA mass removal.

Figure
10

Attachment A

Groundwater Hot Spot and DAPL Removal



Information Needed for FS Alternatives Evaluation

1. Agreement on Volume and Mass of NDMA in Main Street DAPL pool, diffuse layer
2. Concurrence for Groundwater Hot Spot Alternatives
3. Endpoints for Source Control/Removal (DAPL Extraction and Hot Spots (… where does hot spot removal end and GW remediation begin?)

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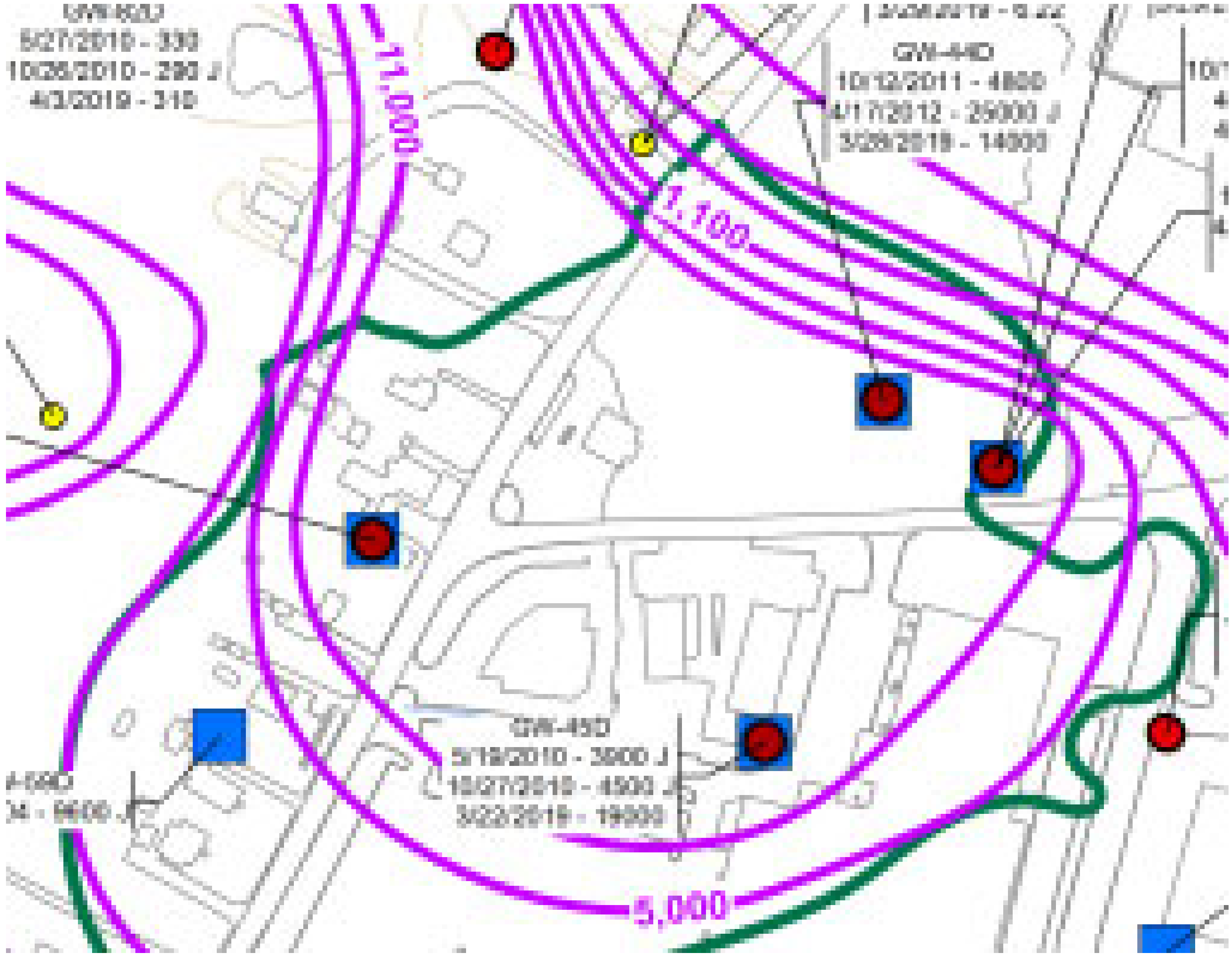
Explanation of NDMA Isopleths



Agenda/Objectives

Part I: Evaluate DAPL volume calculations

- There is a paucity of data but more will be collected in the DGWP Phase I and II to improve accuracy
- Olin thinks that the volume estimates are OK for FS purposes

Part II: Estimate the NDMA mass in DAPL pools and groundwater

- DAPL will be pumped down which will manage the overlying hot spot
  - South Ditch analog
- Implications for NDMA mass distribution and cleanup priorities
- A reasonable mass estimate is necessary to evaluate alternatives

Part III: Evaluation of DAPL pool hot spot remediation benefit

- Review technical implementability
- Is DAPL hot spot removal the correct option in the FS?
- Define NDMA extraction success metrics

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Observations and Definitions

- Analysis is based on current data set amended by recent re-analysis of NDMA in select MP ports
- “Hot spot” groundwater = NDMA >5,000 ng/L
- “Hot spot” present within diffuse layer overlying Main Street DAPL pool
- Volumes/masses calculated by Nobis and Olin similar
- Very small mass contribution from diffuse layer/overlying groundwater

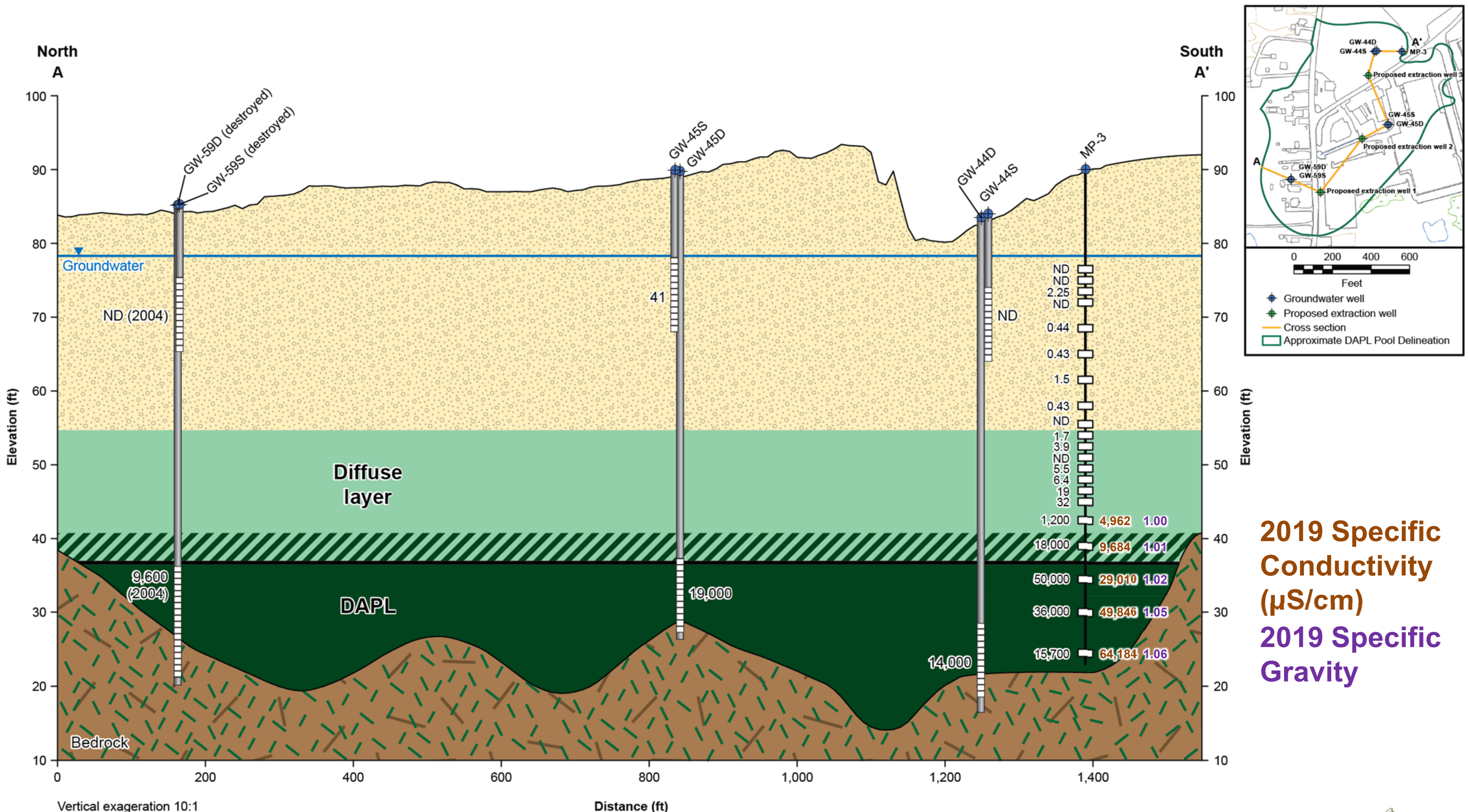
Main Street DAPL Elevation is 38.5 ft amsl (Base of #4)

Main Street (MP-3)						
Port	**Port Base**	**Lithology**	**SG (2012) Measured**	**SG (2019) Measured**	**NDMA (2019)**	**Material**
5	42	Gravel/ Cobbles (sand matrix)	1.004	1.001	1,200	Diffuse Layer
4	38.5	Gravel/ Cobbles (sand matrix)	1.008	1.007	18,000*	Diffuse Layer (Hot Spot)
3	34	Gravel/ Cobbles (sand matrix)	1.028	1.021†	50,000*	DAPL
2	29.5	Gravel/ Cobbles (sand matrix)	--	1.047	36,000*	DAPL
1	24	Gravel/ Boulders (sand matrix)	--	1.059	15,700	DAPL

1) SG in #4 was 1.02 in May 2005 †SC was ~29,000 µmhos/cm in 8/2019 so conservatively assumed to be DAPL

***Re-sampled (preliminary data)**

Main Street DAPL Section A-A'
Top-of-DAPL at 36.8 ft. amsl (2019)



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DAPL Volume Calculation Method

- Areas within contours of bedrock surface up to Top of DAPL (ToD) surface (between the base of screen for sampling ports)
  - The stacked slices were summed, i.e.;

$$V(ft^3) = \sum [A(ft^2) \times H(ft)]$$

- Assumed 25% porosity
- 2019 data indicates:
- Main Street ToD is at 38.5 ft amsl (base of MP-3 port 4)
- Jewel Drive ToD is at 50.6 ft amsl (base of MP-2 port 4)
  - Actually lower at EW-1 (48.9-49.4 ft amsl)
- Containment Area ToD is at 51.4 ft amsl (base of MP-1 port 3)

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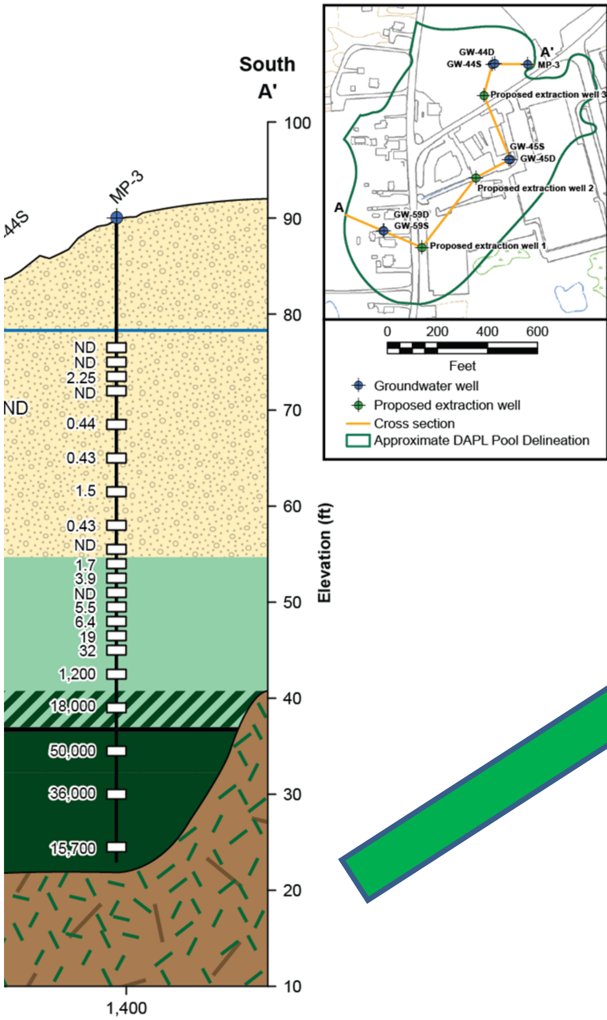
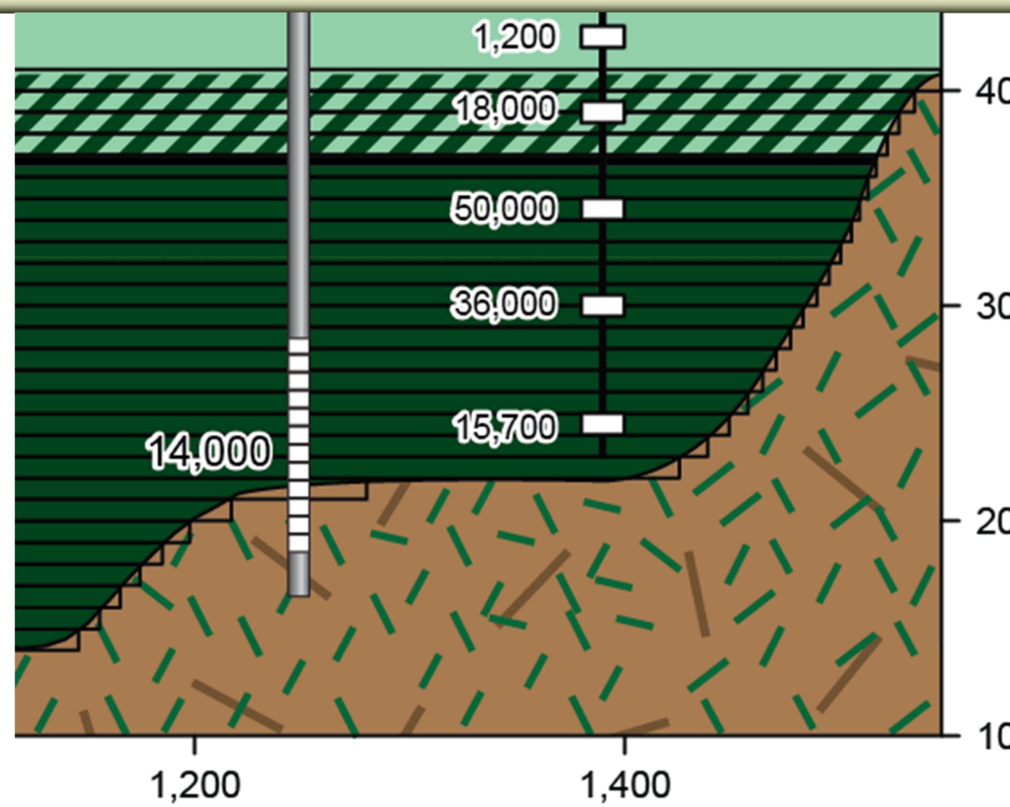
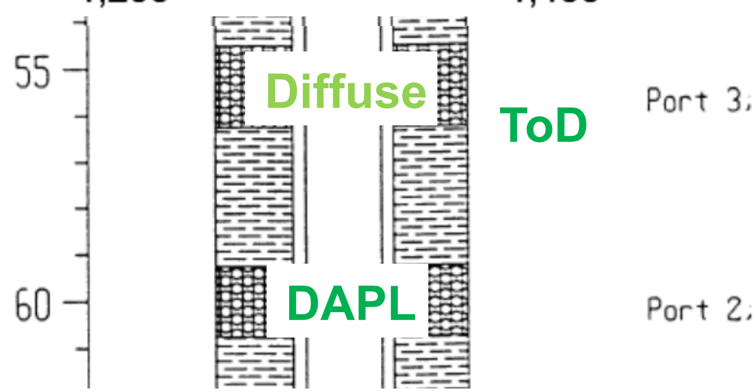
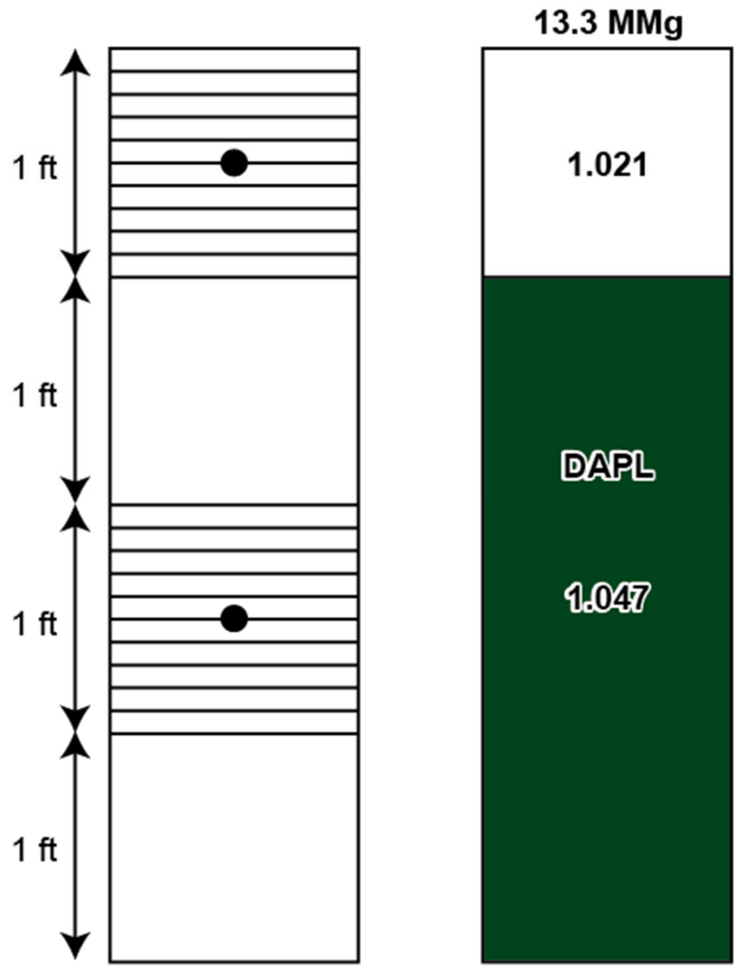
DAPL Volume Calculation Schematic: ToD Assumed at the Base of the Diffuse Port







Estimated DAPL Volume in Main Street Assuming the Base of the Port Above DAPL



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Comparative DAPL Pool Volumes (Million Gallons)

	Main St.	Jewel Dr.	CA
EPA/Nobis (recommended) 40.75 ft amsl	17.5	1.4	0.61
EPA/Nobis (EPA CSM) 40.75 ft amsl	21.2	1.4	0.66
Geomega (38.5 ft amsl)	**13.3**	**1.3**	**0.24**
Olin OU3 RI (39.25 ft amsl)	13	1.0	0.20

GEOMEGA

Reasons for Nobis/Olin Differences are the Result of Selected Input Parameters

	Main St.	Jewel Dr.	CA
EPA/Nobis (recommended)	42 ft amsl n= 0.25	49.4 ft amsl (ML-1)	54.9 ft amsl
EPA/Nobis (EPA CSM)	42 ft amsl n= 0.29	49.4 ft amsl (ML-1)	54.9 ft amsl
Geomega	**38.5 ft amsl n= 0.25**	**50.6 ft amsl (MP-2)**	**51.4 ft amsl 2019 data**
Olin OU3 RI	39.25 ft amsl n= 0.25	48.9 ft amsl	51 ft amsl

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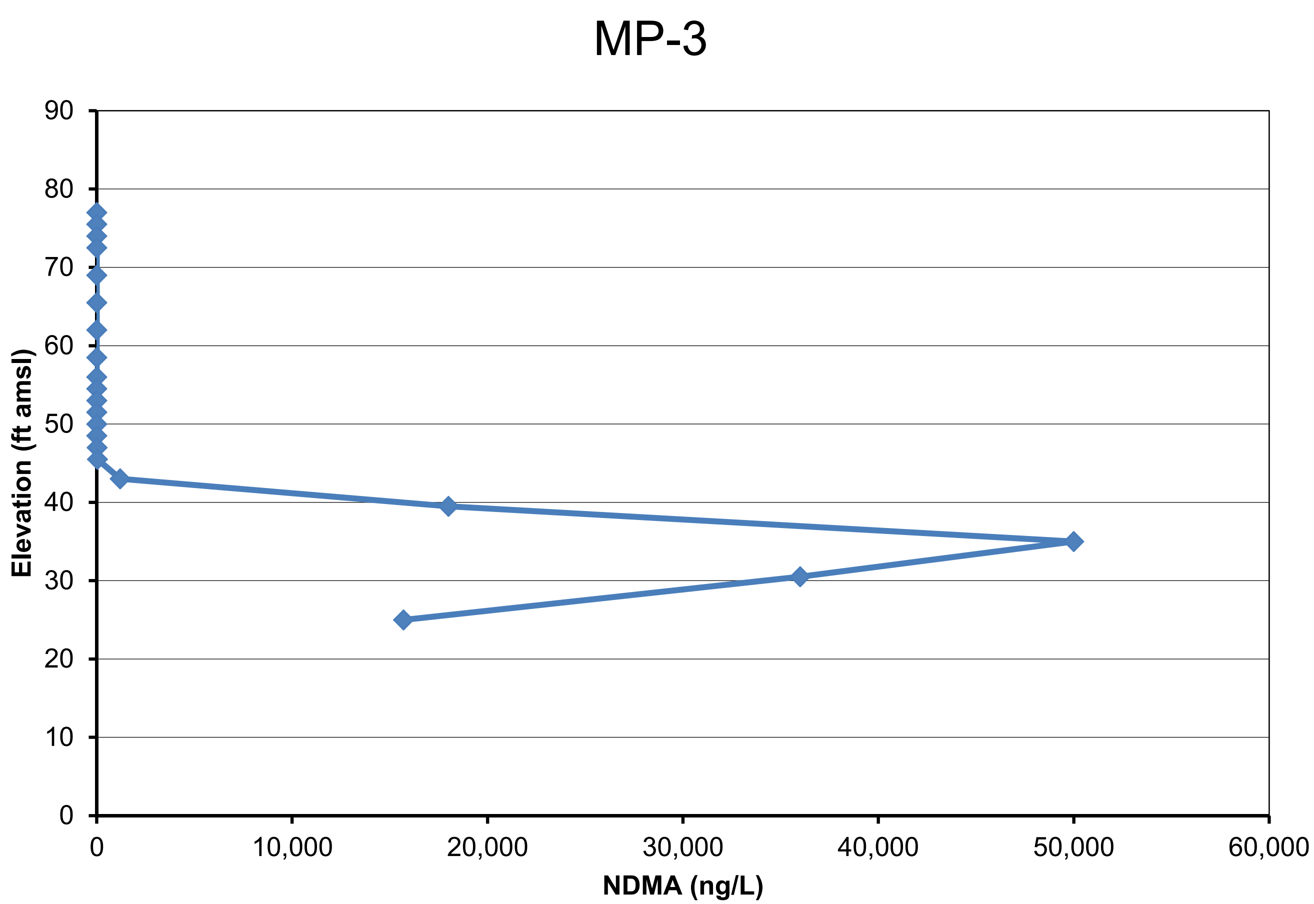
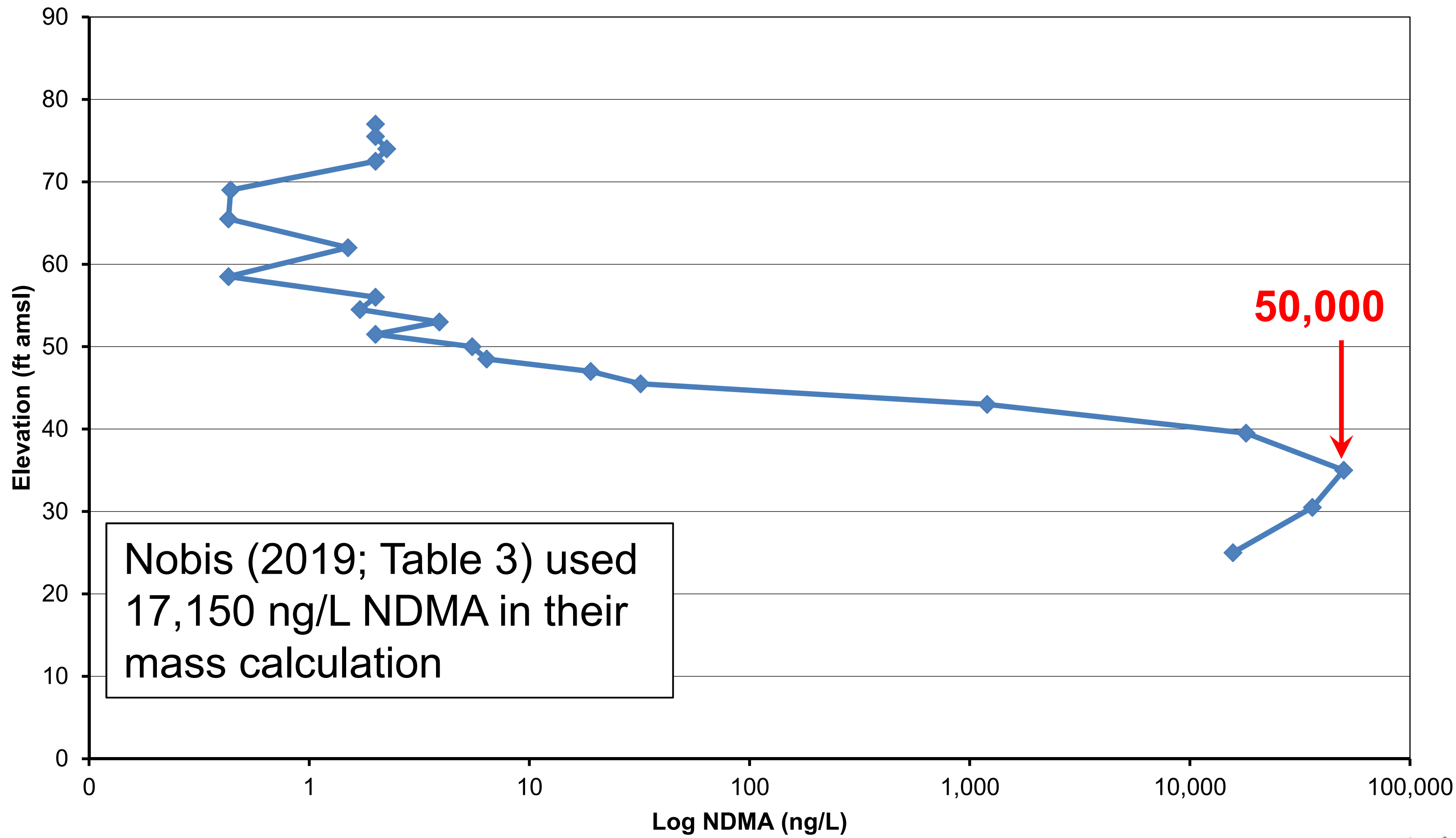
Part II: NDMA Mass

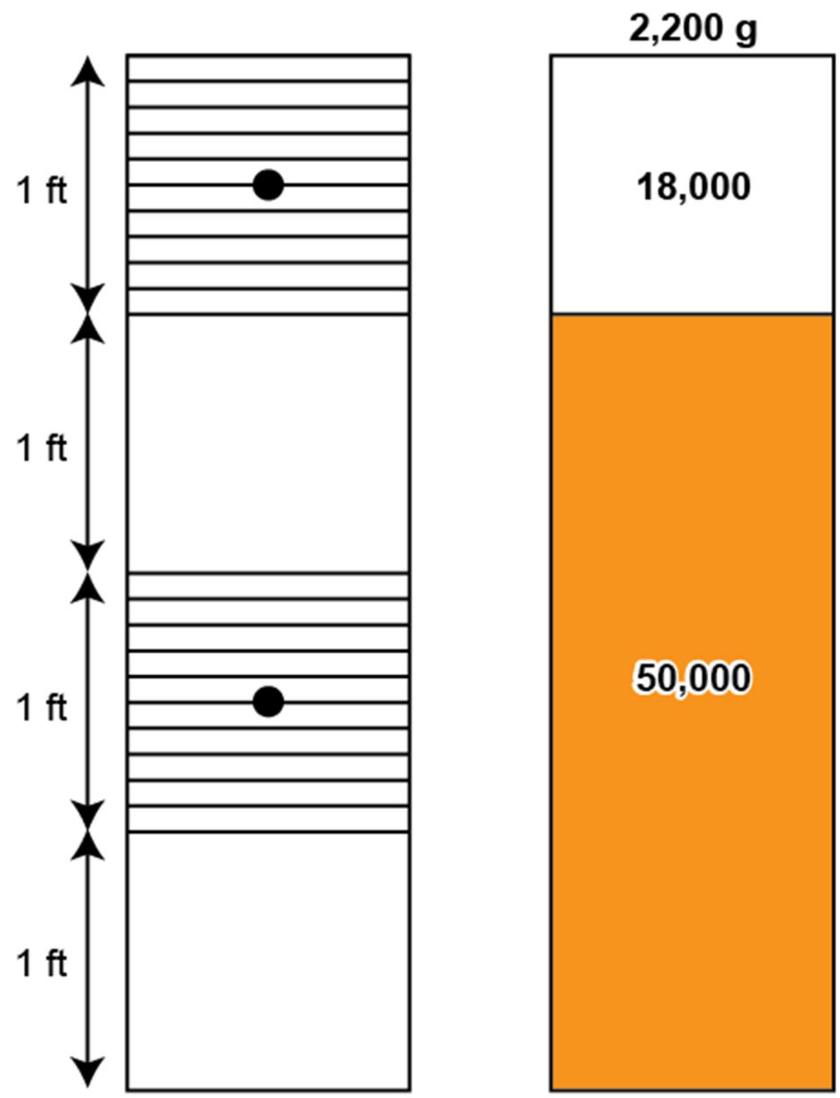


Preliminary NDMA in the Main St. DAPL Pool (MP-3 2019 log scale)



GEOMEGA

Estimated NDMA Mass in Main Street DAPL Assuming the Base of the Port Above DAPL



GEOMEGA

NDMA Mass Estimates in Grams

Location	Nobis	Geomega
Main St. DAPL Pool (base of port)	980	2,170
Main St. DAPL Pool (hot spot layer)	--	140
OPWD DAPL Pool	14	21
OPWD (diffuse layer: 50-55 ft amsl)	--	2.4
CA DAPL Pool (base of port #4)	2.4	29
MMB Overburden (>5,000 ng/L)	915	915*

*Adopted from Nobis estimates for FS evaluation purposes

GEOMEGA

Reason for Nobis/Geomega Differences

Location	Nobis	Geomega
Main St.	Used Average 17,150 ng/L Used 16 MM gals	#2: 36,000 ng/L #3: 50,000 ng/L Used 13.3 MM gals
Jewel St.	Used Average 3,400 ng/L ToD 48.9-49.4 ft amsl (ML-1)	6,700 ng/L in DAPL ToD 50.6 ft amsl (MP-2)
CA	Used Average 1,165 ng/L	5,600 in DAPL Added 13,000 in #3

*Port 3 recognized as an NDMA “hot spot”

GEOMEGA

Main Street NDMA DAPL Mass (in grams): Geomega and Nobis Estimates Similar

Location	Nobis	Geomega
Main St. DAPL Pool (base of port)	980	2,200
Main St. DAPL Pool (base of port) using Nobis' average NDMA concentration of 17,150 ng/L	--	860

GEOMEGA

NDMA Mass in DAPL Estimates in Grams using the Nobis Volumes

Location	Nobis	Geomega Nobis*
Main St. DAPL Pool (base of port)	980	TBD
OPWD DAPL Pool	14	TBD
CA DAPL Pool (base of port #4)	2.4	TBD

*Olin is estimating/finalizing the mass using Nobis volumes and 2019 groundwater data

GEOMEGA

Part III. Benefit Analysis of Pumping Hot Spot Groundwater (Main St. DAPL)

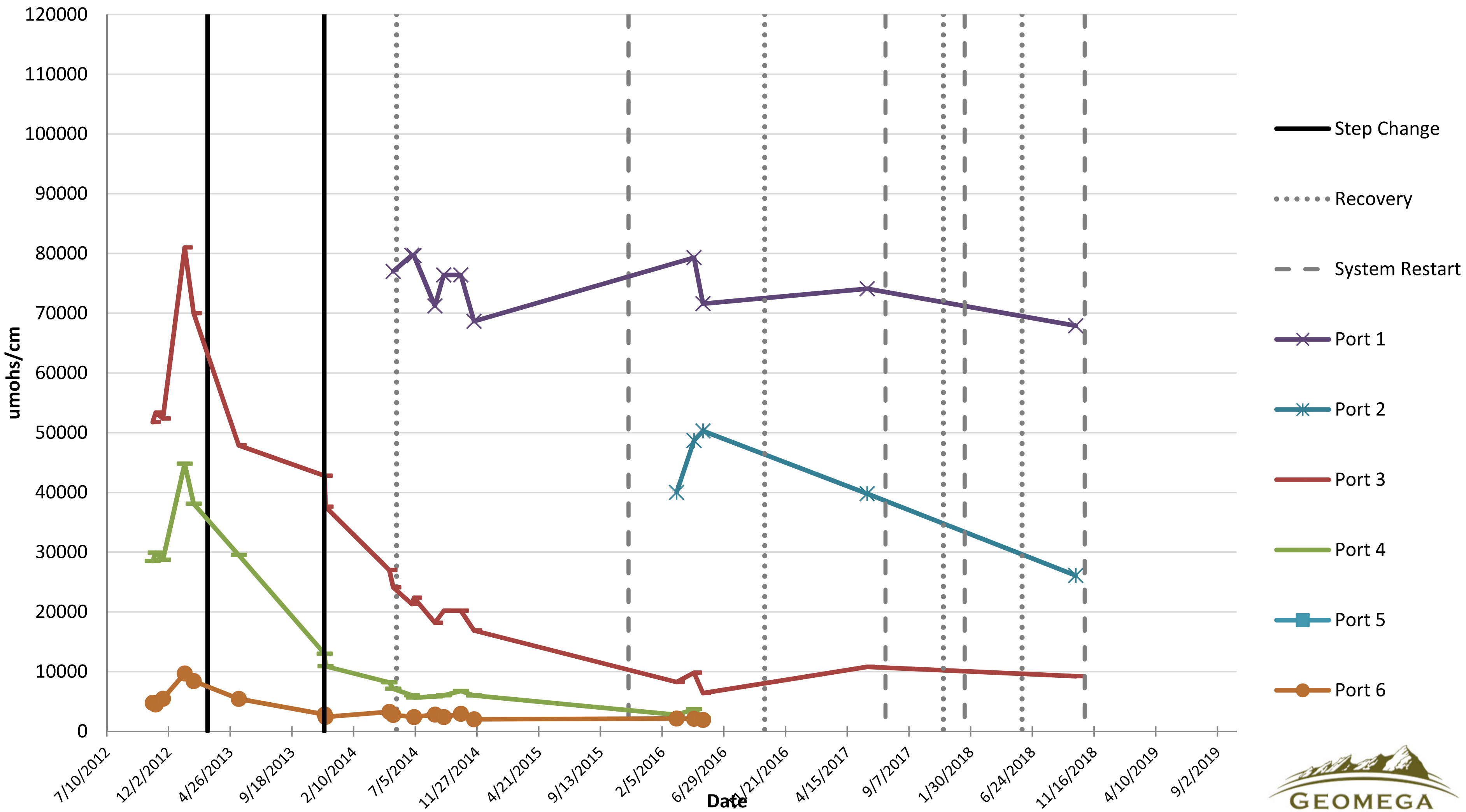
Jewel Drive Provides a Harbinger for Main Street DAPL Reduction

Jewel Drive (MP-2)						
Port	Port Base	Lithology	SG (2012) Measured	SG (3/19) Measured	NDMA (ng/L) 2019	Material
7	57.6		1.004	--	48 **(420)**	Ground water
6	56.1	Gravel/ Cobbles (sand matrix)	1.008	1.000	56 **(1100)**	Ground water
5	54.6	Gravel/ Cobbles (sand matrix)	--	--	--	No Data Collected
4	53.1	Gravel/ Cobbles (sand matrix)	1.03	1.005	240	Diffuse Layer
3	50.6	Gravel/ Cobbles (sand matrix)	--	1.063§	920*	Diffuse Layer
1	45.6	Boulders/ Cobbles (sand matrix)	1.1	1.053	6,700	DAPL

2012 data §SG inconsistent with SC ***Re-sampled (preliminary data)**

GEOMEGA

MP2 Port #3 has been Consistently ≤10,000 μmhos/cm Since 2016



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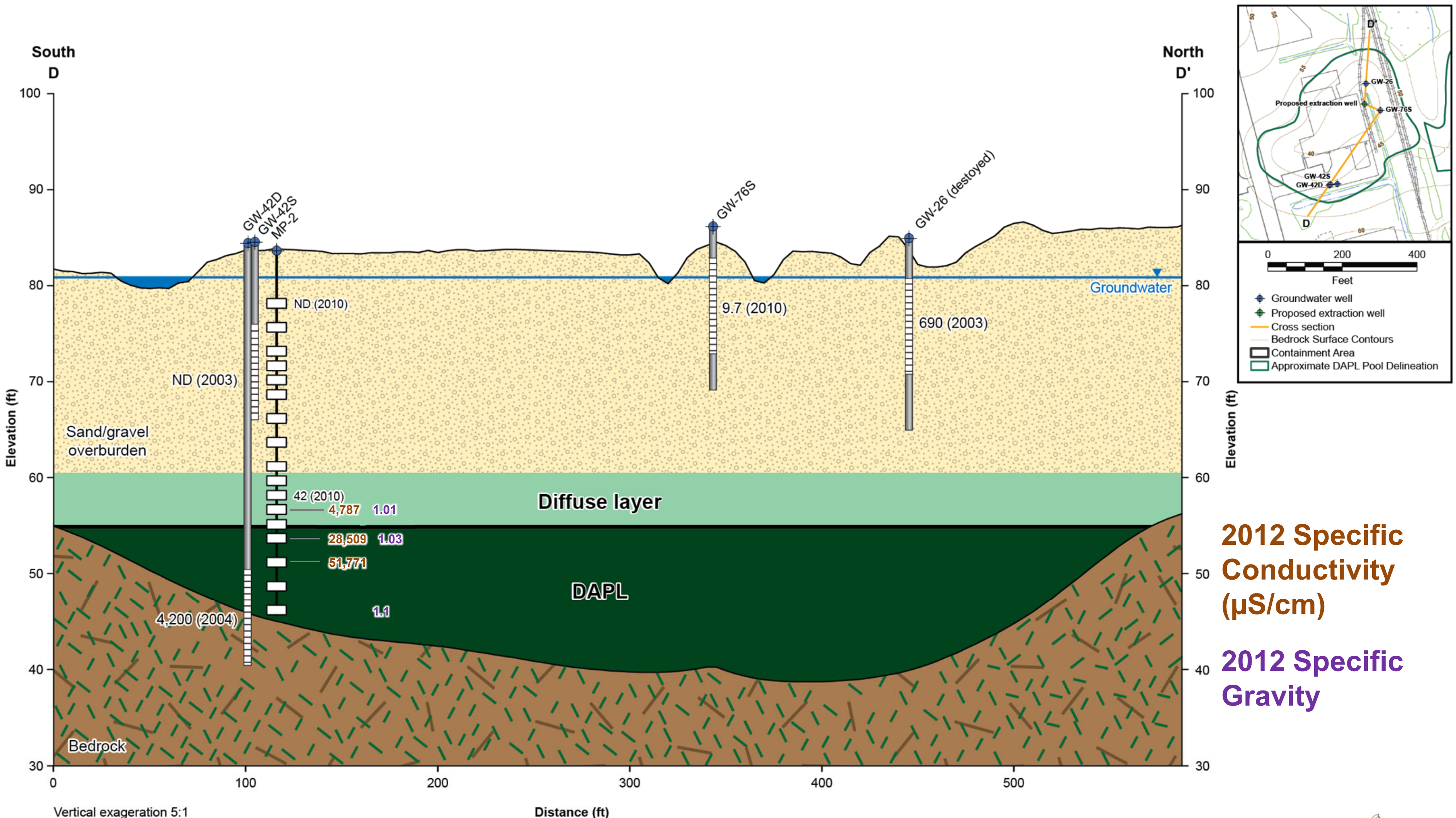
OPWD DAPL Pool in 2012

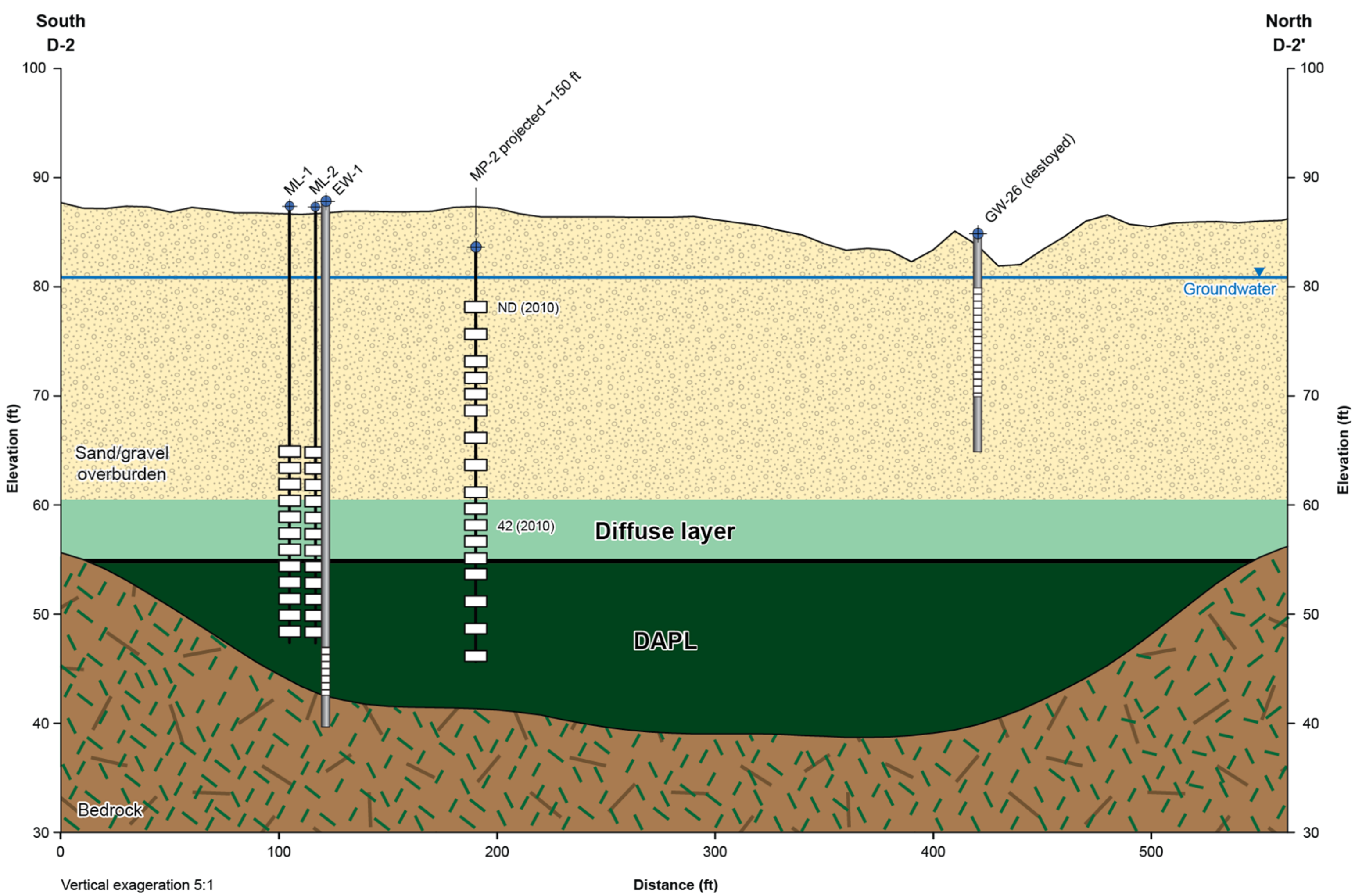


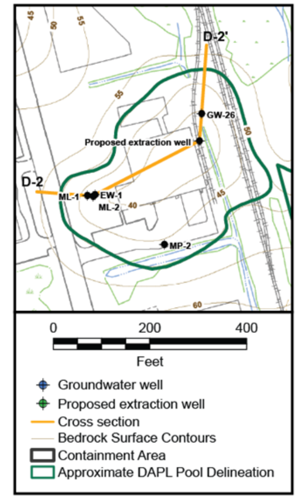
2012 Specific Conductivity (µS/cm)

2012 Specific Gravity

GEOMEGA

OPWD DAPL Pool in 2012: Pre-Extraction Consistent Diffuse Layer Elevations





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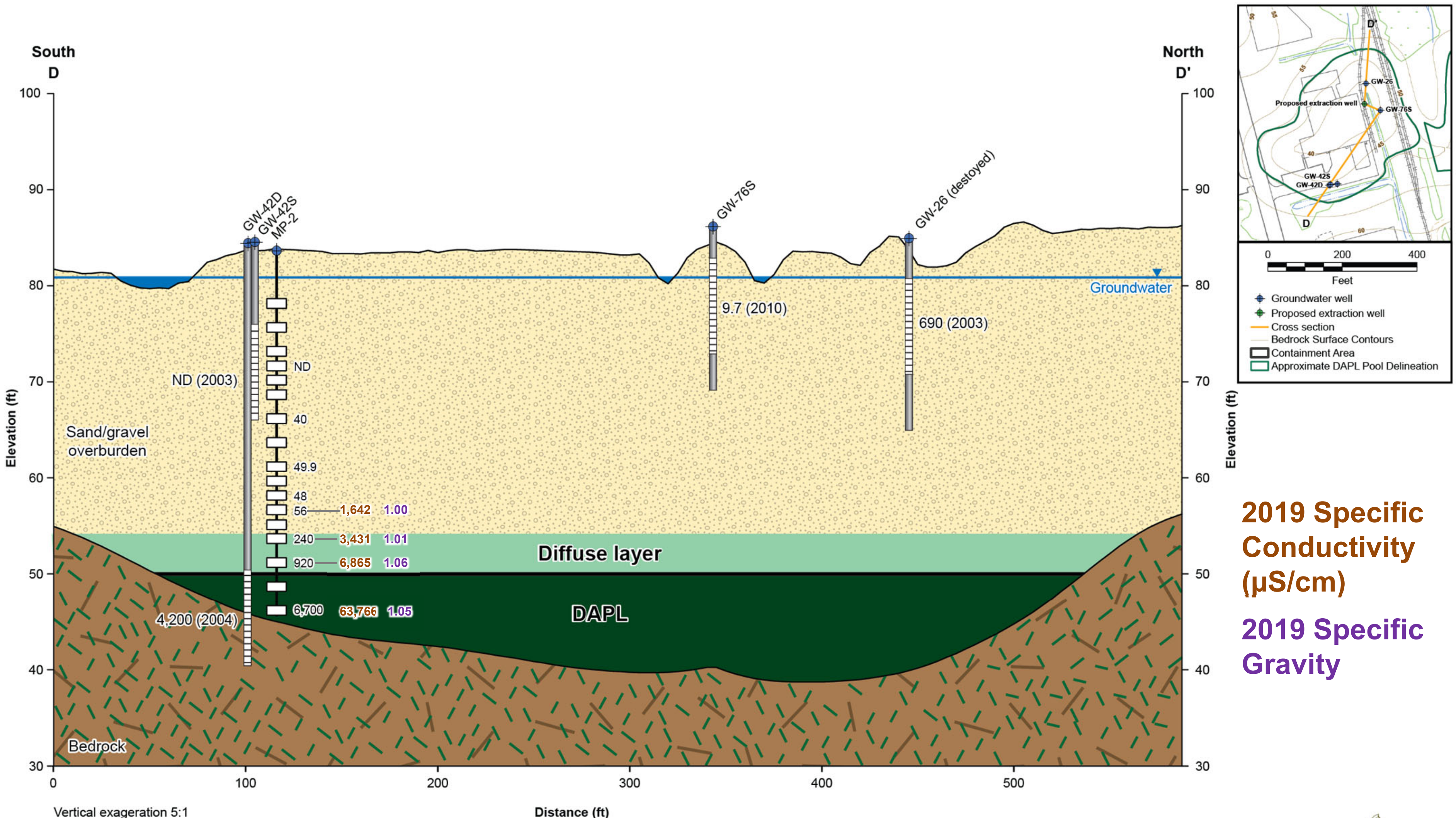
OPWD DAPL Pool in 2019 After ~1.0 MM Gallons of DAPL Removed



2019 Specific Conductivity (µS/cm)

2019 Specific Gravity

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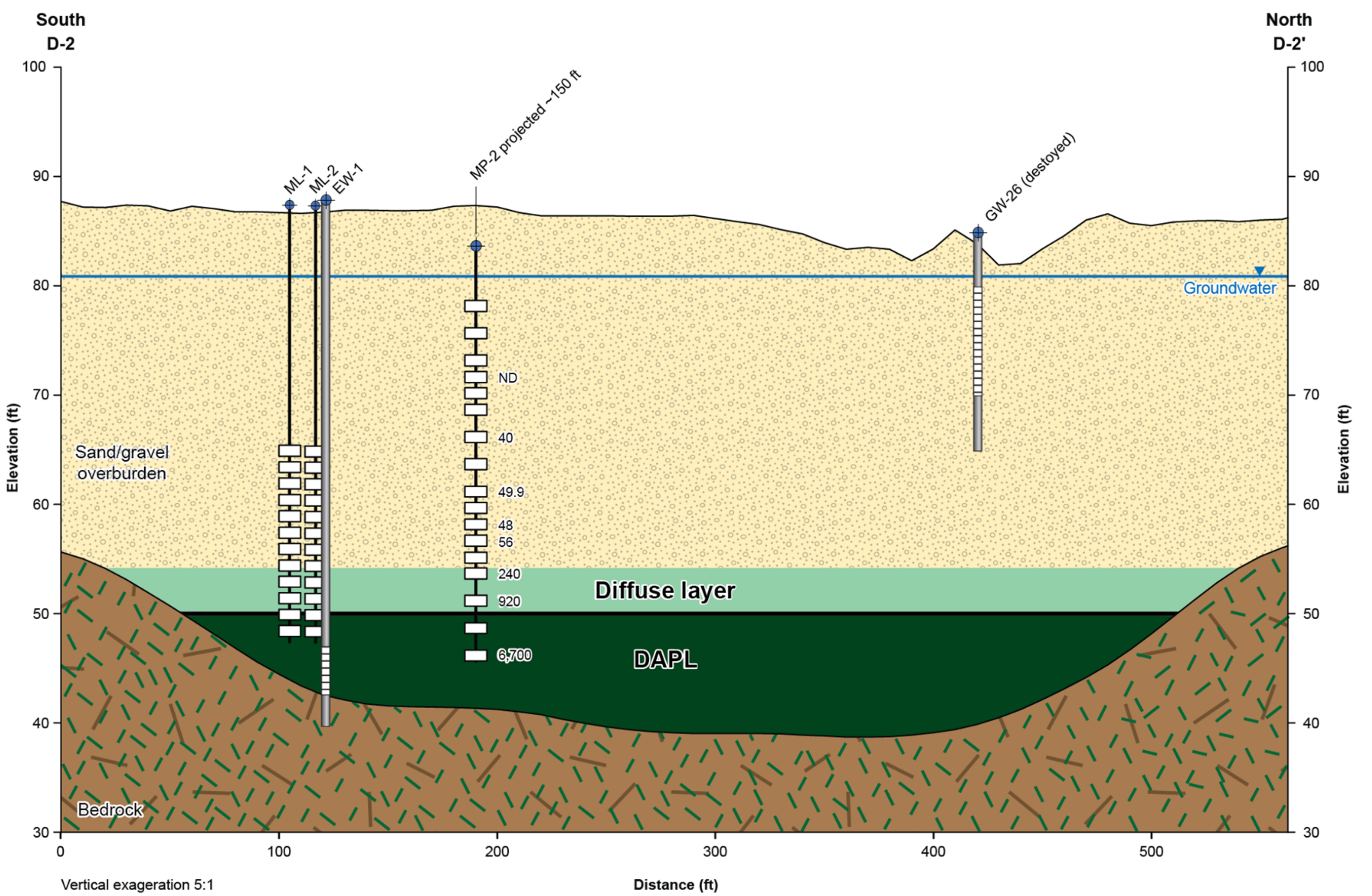
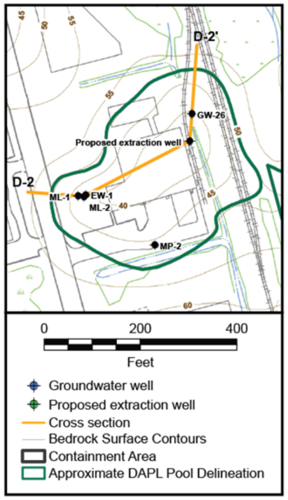
OPWD DAPL Pool in 2019
Consistent Diffuse Layer Elevations





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Lessons Learned from OPWD DAPL Removal

- ~1 million gallons of DAPL have been removed over the last 7 years
- The DAPL elevation has decreased by ~5 feet
- The DL elevation has also decreased by ~6 feet
- DL Solute concentrations have decreased by ~1 order of magnitude
- There is ~2.4 g of NDMA in the OPWD diffuse layer (50-55 ft amsl)

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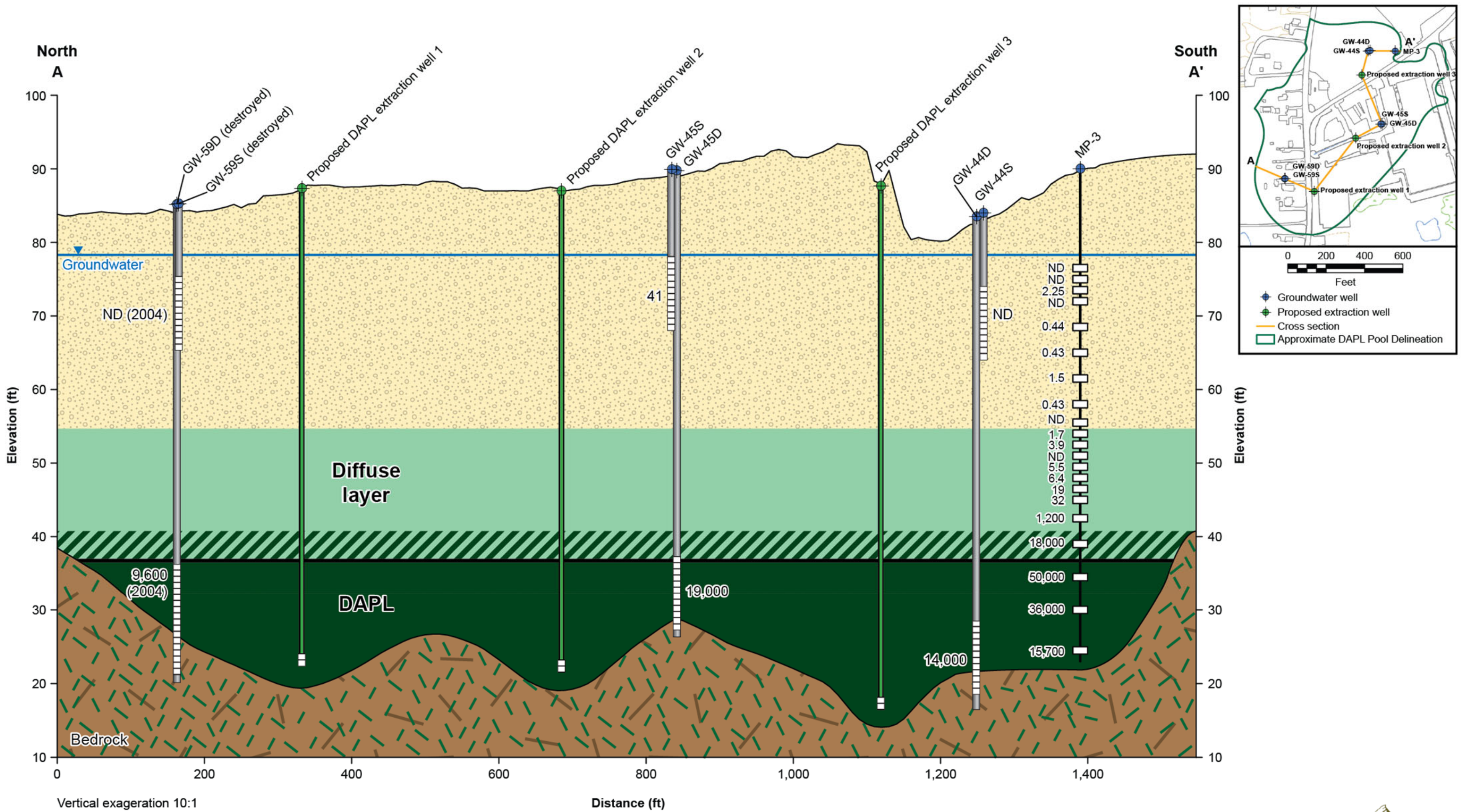
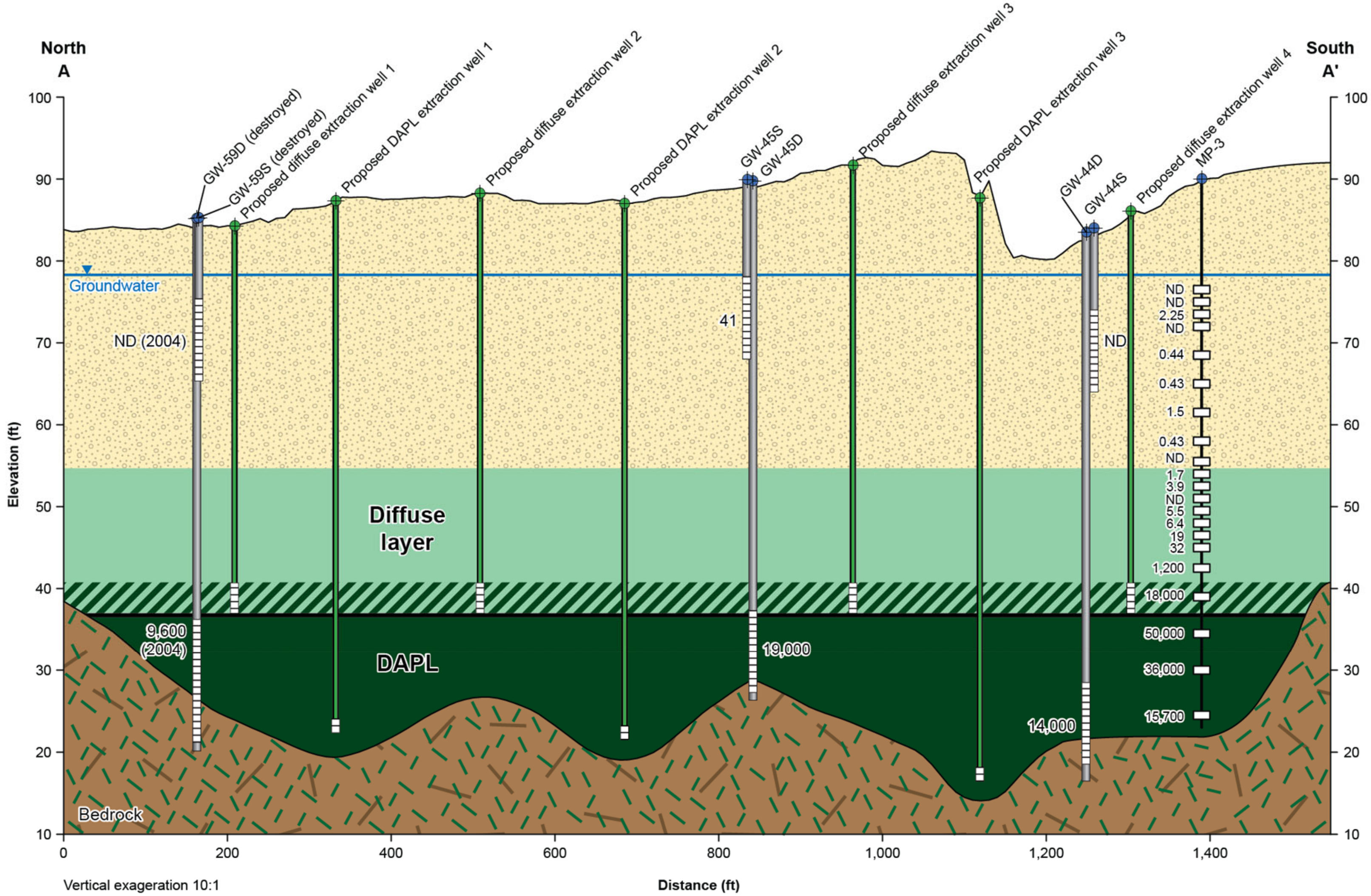
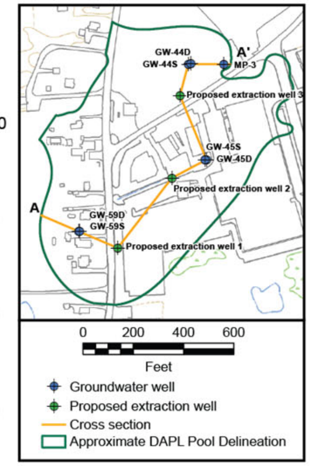
Conceptual Main Street DAPL Pool Extraction Wells



GEOMEGA

Conceptual Main Street DAPL Pool Extraction and Hot Spot Wells





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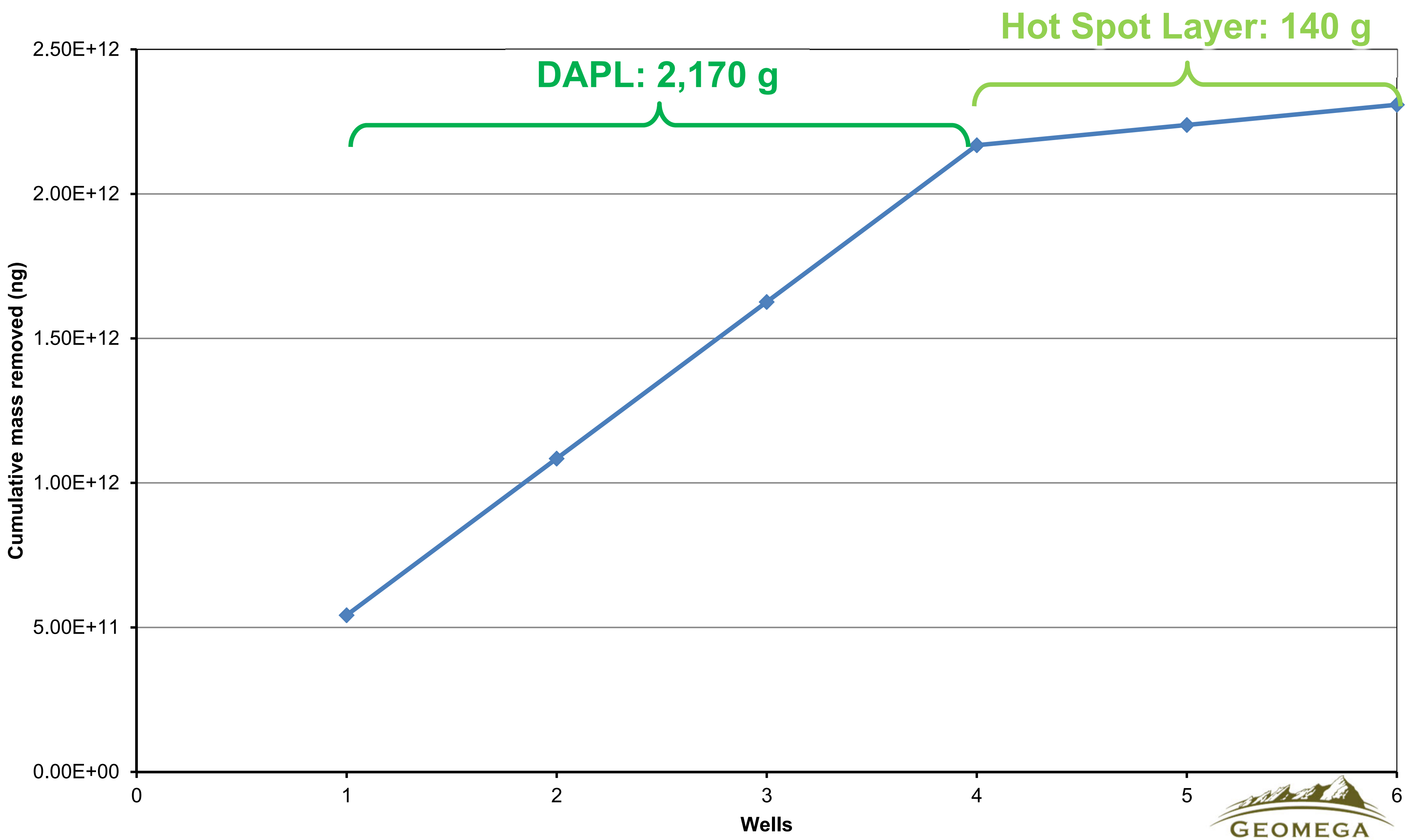
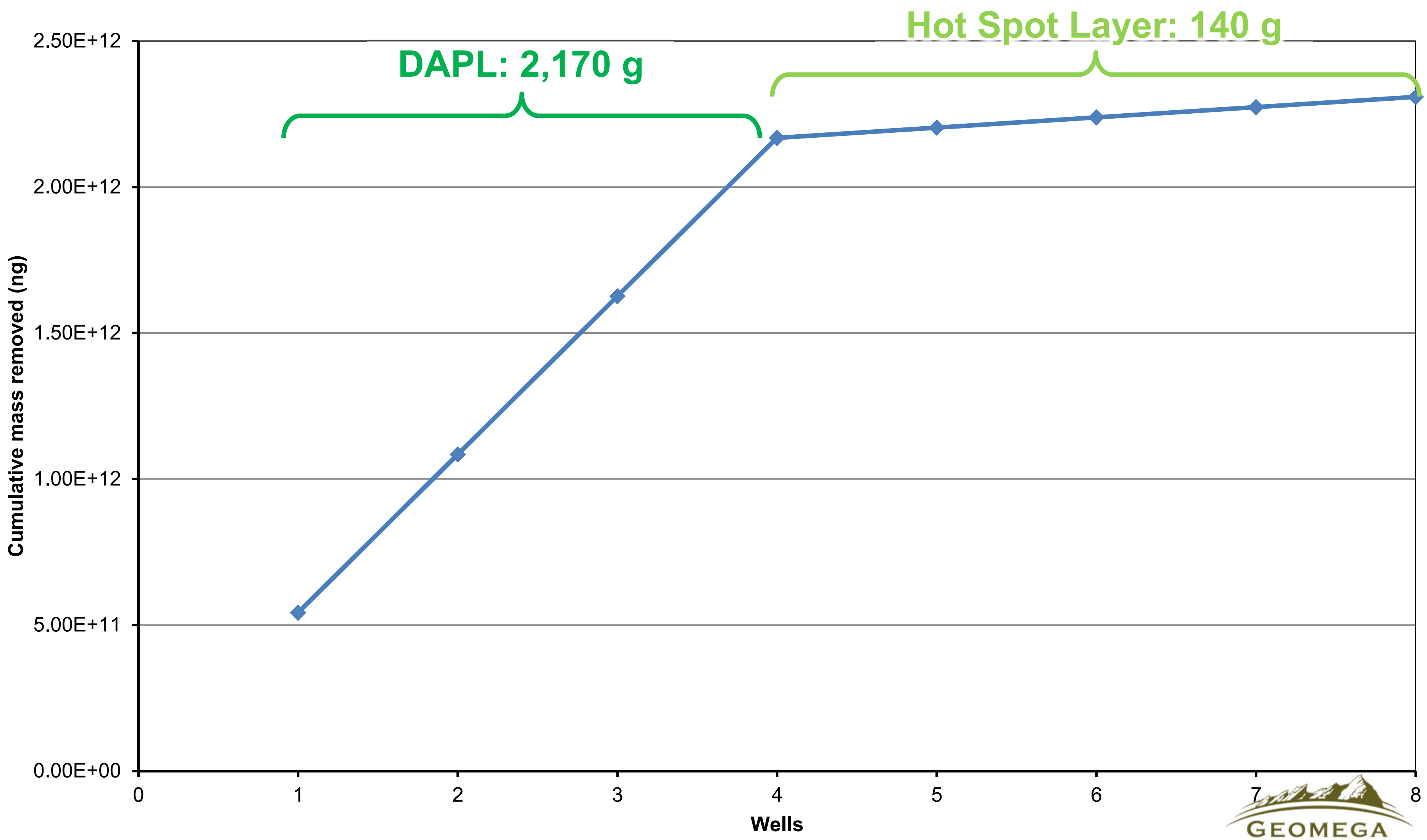
Cumulative Simulated Mass Removed Assuming 6 Wells (2 in the Hot Spot)

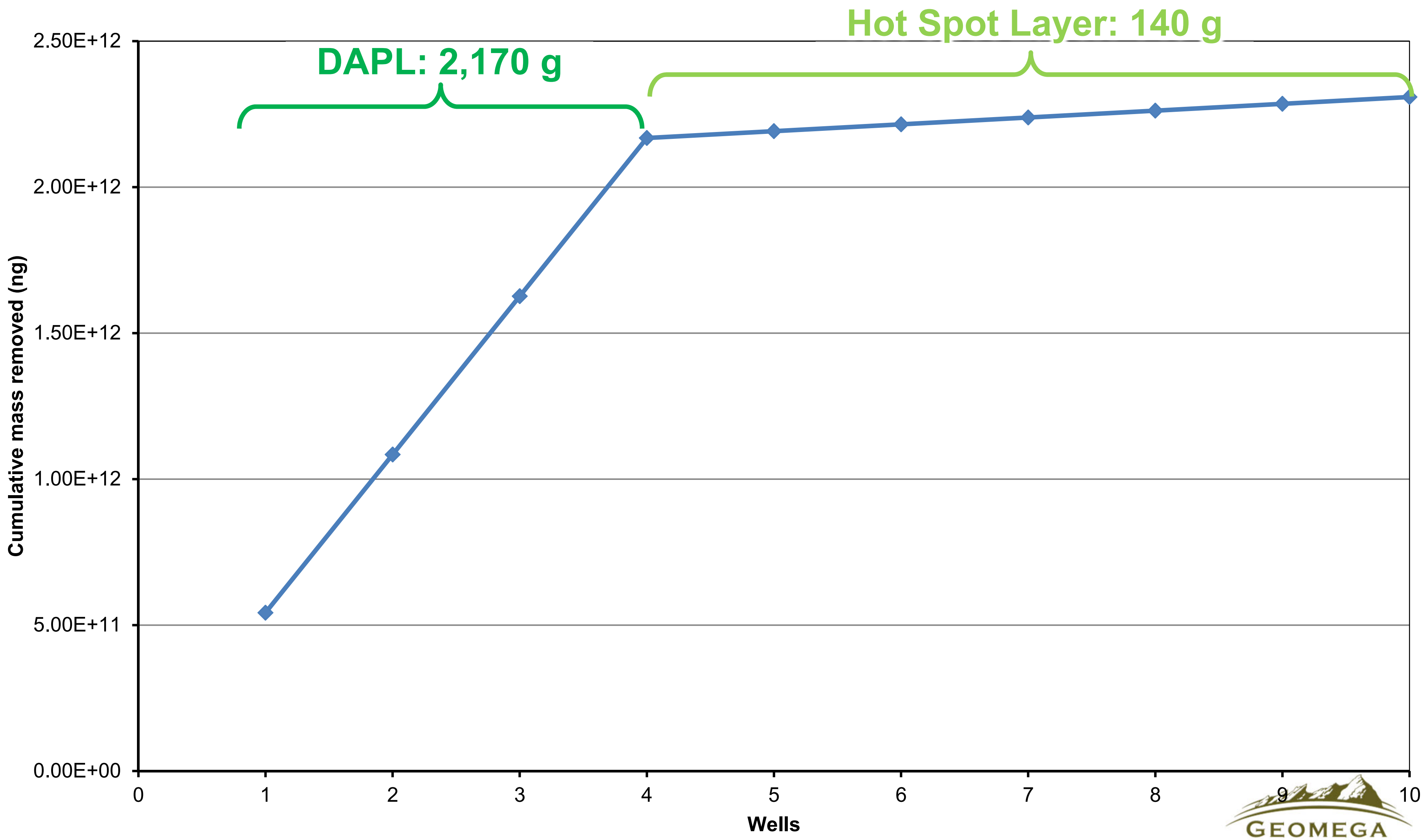


GEOMEGA

Cumulative Simulated Mass Removal Assuming 8 Wells (4 in the Hot Spot)



Cumulative Simulated Mass Removed Assuming 10 Wells (6 in the Hot Spot)



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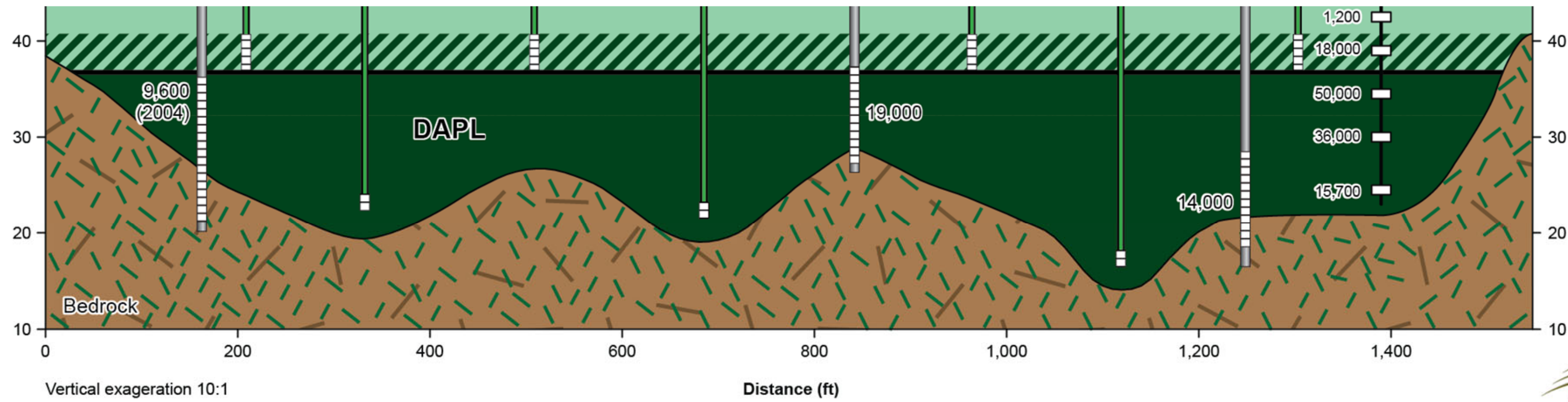
Main Street Diffuse Layer Conclusions

- DL has little NDMA mass compared to DAPL – NDMA mass in the Main Street hot spot layer (6%) compared to DAPL (94%)
- Targeting and remediating a thin layer (~3 ft) of NDMA-bearing groundwater is challenging given the vagaries of:
  - Ongoing DAPL/DL drawdown rendering the pumping wells ineffective (stranded)
  - Lateral temporal DAPL/hot spot interface continuity
- Installation/operation of extraction wells above the DAPL pools would have minimal benefit



Main Street Conclusions: DAPL Extraction

- DAPL is the source of the DL, so removing DAPL will remediate the hot spots
- Main St. DAPL removal provides significant ROI on a NDMA mass basis
- Olin proposes a phased extraction well approach
  - We agree with Nobis' concept of bedrock depression wells
  - The DGWP will drive the number and locations
- Additional extraction wells on the flanks of the depressions will probably exacerbate mixing and a reduction in benefit
- Based on OPWD experience, a short well screen is imperative to maximize DAPL removal
- Olin proposes a SG <1.025 g/cc shut-off metric for DAPL

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Summary

- As agreed, the number of extraction wells will be based on results of Phases I and II following consultation with USEPA
- Hot spot wells above DAPL pools would have technical difficulties with no material/mass removal benefit
- Olin proposes a cumulative mass asymptotic shut-off metric for source removal within groundwater hot spots
- For the purpose of the FS Olin is proposing removal of:
  - ~2,200 grams of NDMA mass from the MSDP
  - 80% of the USEPA's MMB NDMA mass (~730 grams)
  - 1.5 pore volumes to estimate duration
- These estimates will be refined during the pre-design phase after collecting the DGWP data

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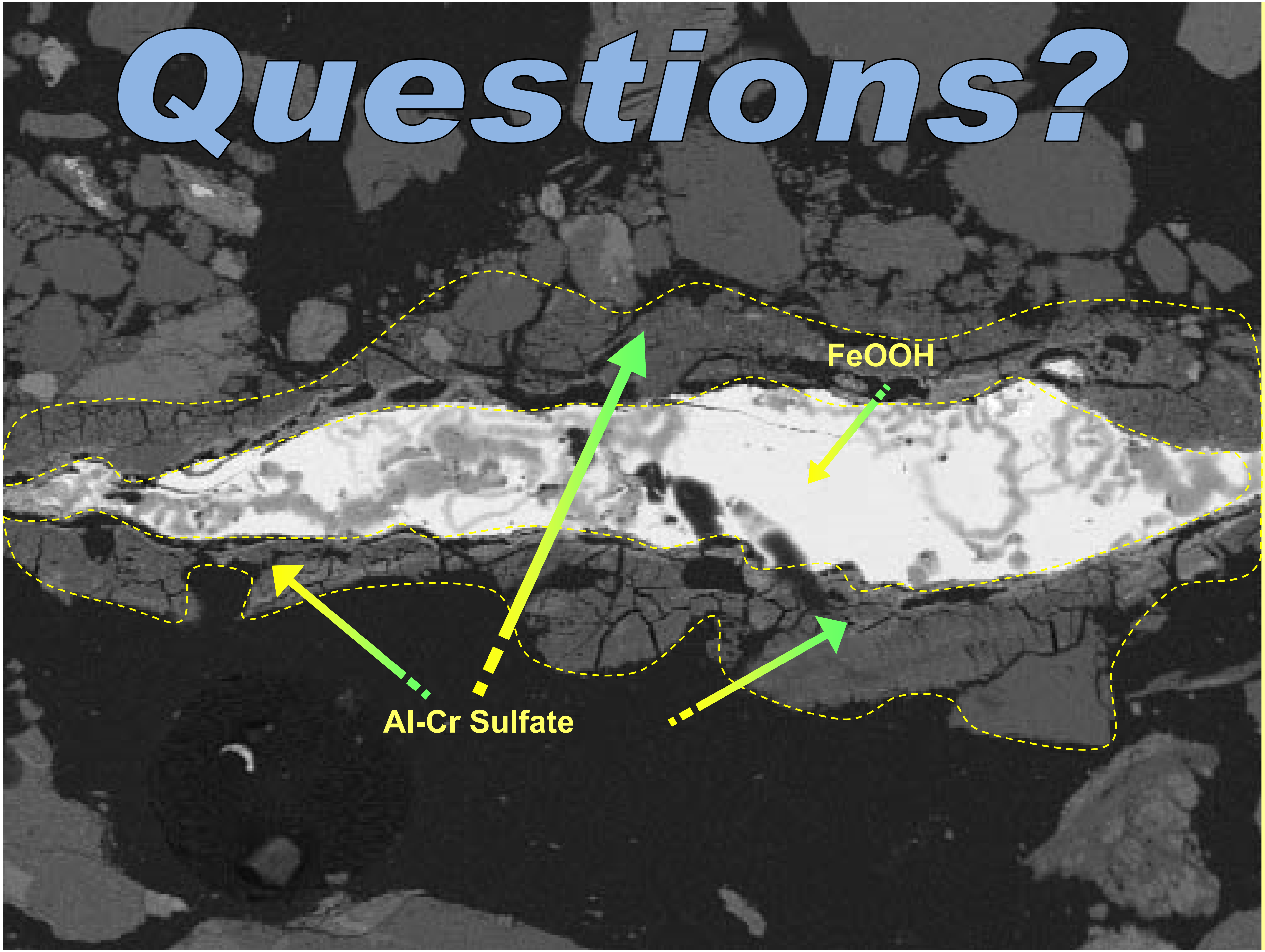
Questions?



Containment Area DAPL Elevation is at 51.4 ft amsl (MP-1: Base of #3)

Containment Area (MP-1 mid-screen)							
Port	Port base	Lithology	SG (2012) Measured	SC (2019) Measured	SG (2019) Measured	NDMA (2019)	Material
6	57.9	Gravel/ Cobbles	1.004	832	1.00	240	Diffuse Layer
5	56.4	Gravel/ Cobbles	1.004	1,853	--	--	Diffuse Layer
4	53.9	Gravel/ Cobbles	1.008	6,966	1.00	4,600	Diffuse Layer
3	51.4	Gravel/ Cobbles	--	25,181	1.020	13,000	Hot spot Layer
1	46.4	Boulders/ Cobbles	1.102	84,774	1.091	5,600	DAPL

Note: 1) Nobis selected ToD 53-9-54.9 (#4 screen interval)

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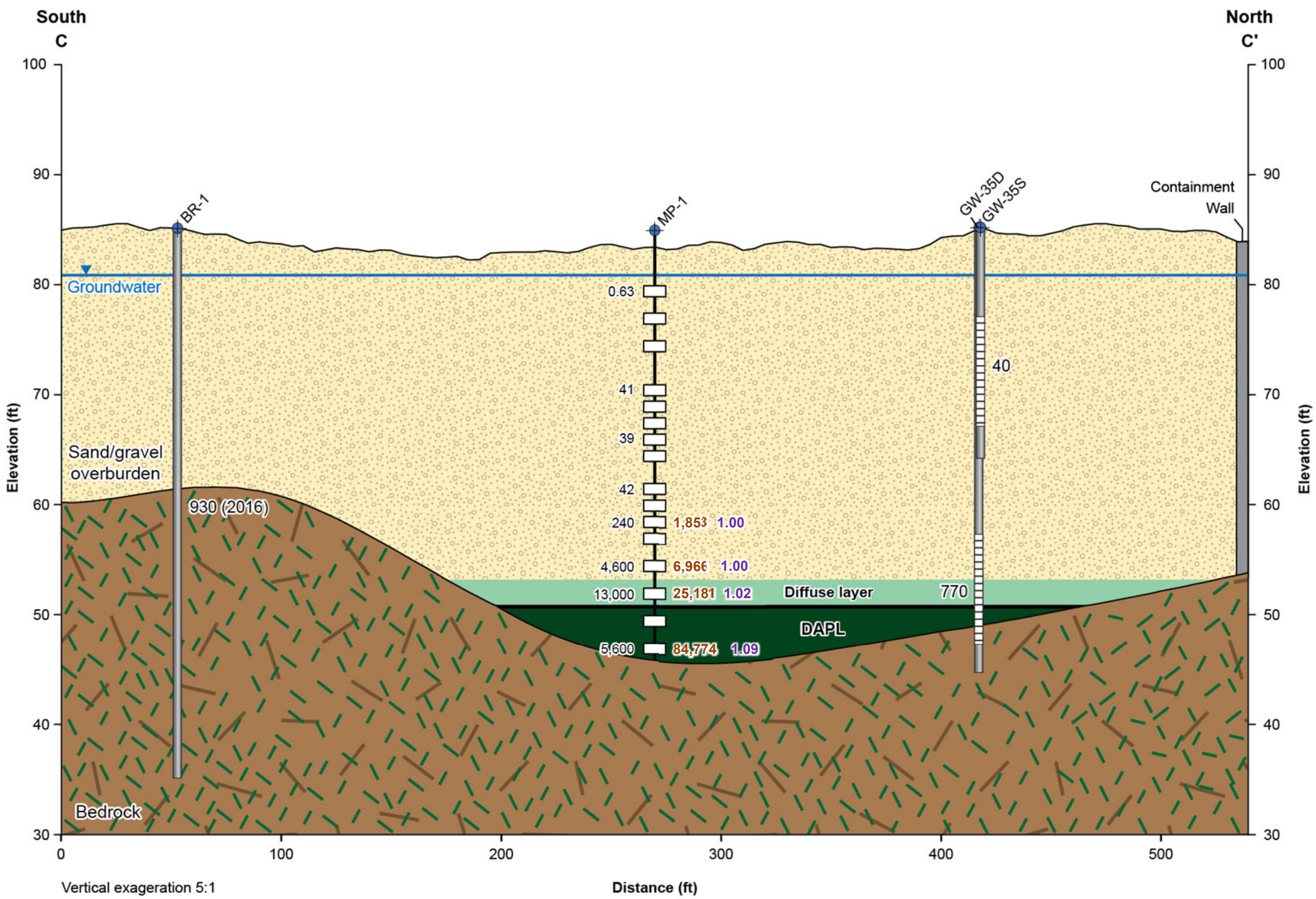
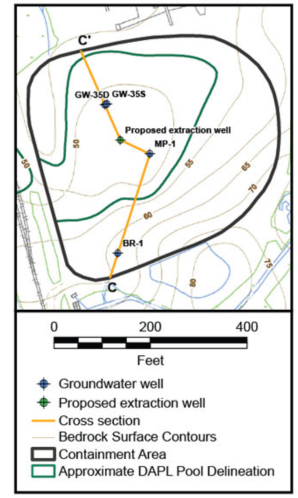
Containment Area DAPL Pool C-C' Diffuse layer with Hot Spot NDMA





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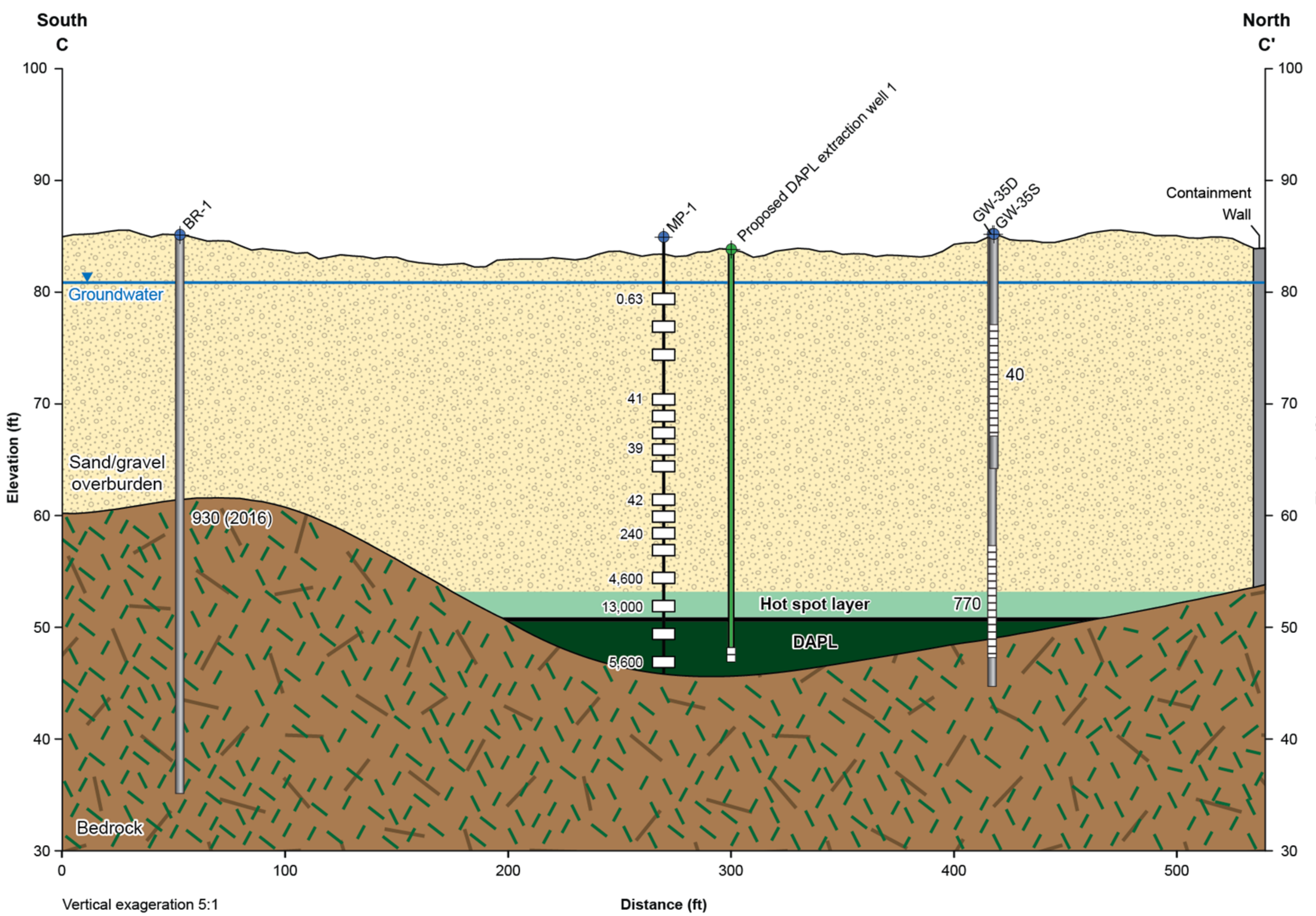
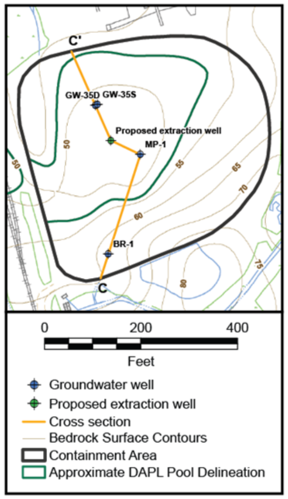
Containment Area Extraction Wells





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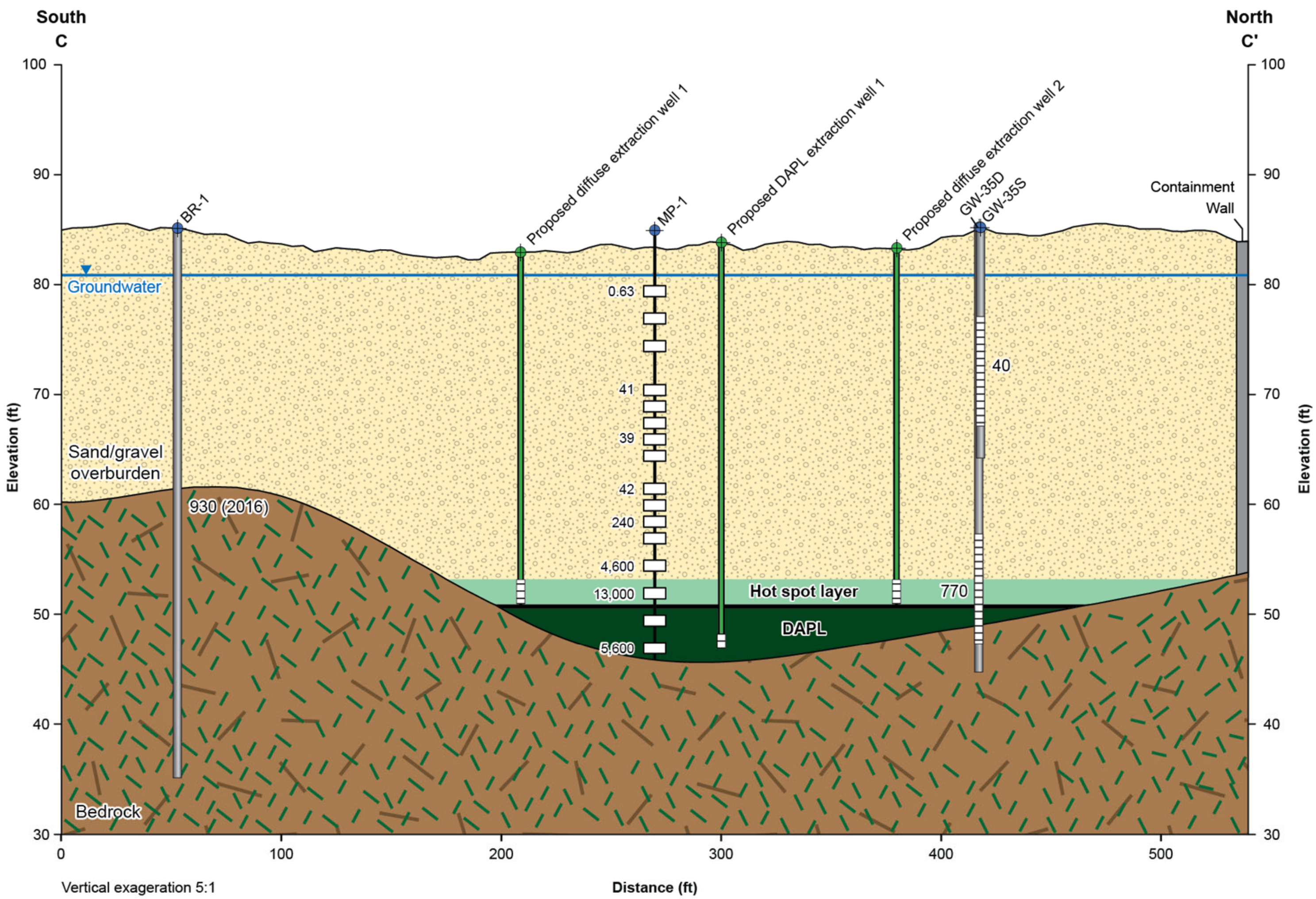
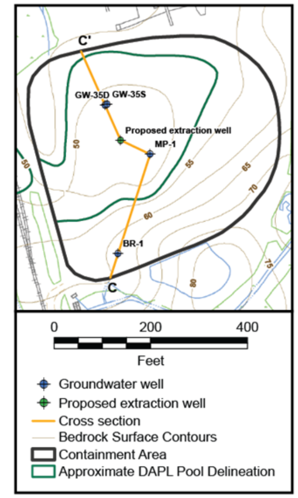
Containment Area Extraction and Hot Spot Wells





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